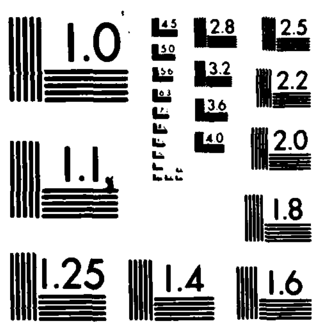
AD-A139 574 OMEGA GLOBAL RADIONAVIGATION A GUIDE FOR USERS(U) COAST GUARD WASHINGTON DC T MACKENZIE ET AL. NOV 83 USCG-COMDTINST-P16566.2 1/1

UNCLASSIFIED F/G 17/7 NL

END
DATE
FILMED
4-84
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

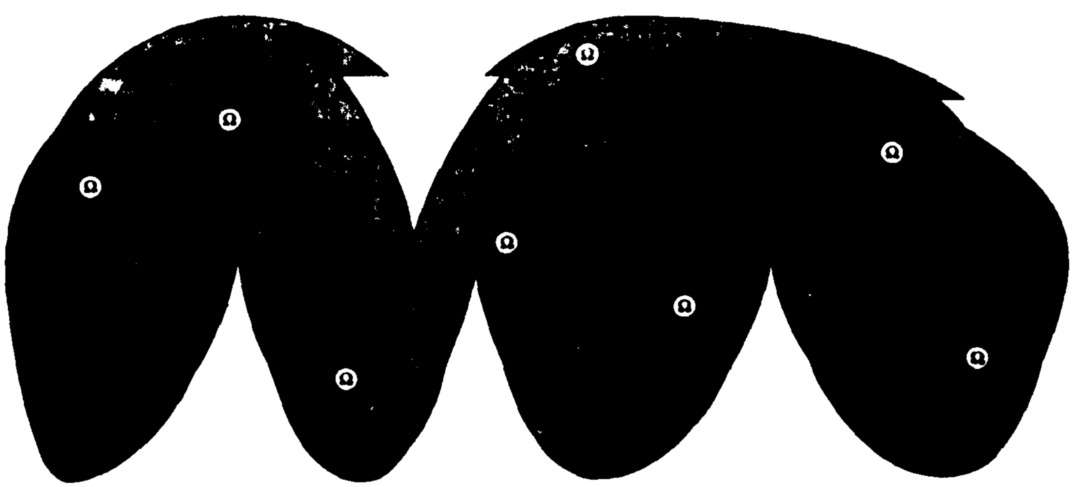
U.S. Department of Transportation
United States Coast Guard

(12)

OMEGA

Global Radionavigation

A Guide for Users



COMDTINST P16566.2 November 1983

How to Use This Index

Place left thumb on the outer edge of this page. To locate the desired entry, fold back the remaining page edges and align the index edge mark with the appropriate paper edge mark.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
COMDTINST P16566.2	AD-A139574	

4. Title and Subtitle
OMEGA GLOBAL RADIONAVIGATION
A Guide for Users

5. Report Date
November 1983

6. Performing Organization Code
DTS-52

7. Author(s)
T. MacKenzie and A. Frost

8. Performing Organization Report No.

9. Performing Organization Name and Address
U.S. Department of Transportation
Research and Special Programs Administration
Transportation Systems Center
Cambridge, MA 02142

10. Work Unit No. (TRAIS)
UM358/R3931

11. Contract or Grant No.

12. Sponsoring Agency Name and Address
U.S. Department of Transportation
U.S. Coast Guard
Office of Navigation
Washington, DC 20493

13. Type of Report and Period Covered
Final Report
Sep. 1981-Nov. 1983

14. Sponsoring Agency Code
G-NRN-2

15. Supplementary Notes

16. Abstract

This publication is an up-to-date handbook for the public about the OMEGA Navigation System. It describes the characteristics of the system and explains how it can be effectively used. This guide reflects the following items noted here for historical significance:

a) 31 October 1972 — OMSTA North Dakota, the first permanent OMEGA station, became operational,

b) 3 July 1978 — Operational responsibility of the OMEGA Navigation System was transferred from the U.S. Navy to the U.S. Coast Guard,

c) 31 December 1980 — The experimental OMEGA Station Trinidad was decommissioned, and

d) 16 August 1982 — OMSTA Australia, the last of the eight permanent stations, became operational.

This publication supersedes the OMEGA Navigation System Users Guide, published by the Navy on 1 March 1978.

17. Key Words
Global Radionavigation, OMEGA, Differential OMEGA, Position Location, OMEGA Stations, Propagation, Signal Format, Signal Synchronization

18. Distribution Statement
Document is available to the public through the Defense Technical Information Center, Alexandria, Virginia 22314

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	64	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

MAILING ADDRESS:
COMMANDANT (G-NRN)
U.S. Coast Guard
Washington, D.C. 2059:
Phone: (202) 426-0990

COMDTINST P16566.2

8 SEP 1983

COMMANDANT INSTRUCTION P16566.2

Subj: OMEGA Global Radionavigation - A Guide for Users

1. PURPOSE. This publication is an up-to-date handbook for the public about the OMEGA Navigation System. It describes the characteristics of the system and explains how it can be effectively used.

2. DISCUSSION. This guide reflects the following items noted here for historical significance:

   a. 31 October 1972 — OMSTA North Dakota, the first permanent OMEGA Station, became operational.

   b. 3 July 1978 — Operational responsibility of the OMEGA Navigation System was transferred from the U.S. Navy to the U.S. Coast Guard.

   c. 31 December 1980 — The experimental OMEGA Station Trinidad was decommissioned.

   d. 16 August 1982 — OMSTA Australia, the last of the eight permanent stations, became operational.

3. DIRECTIVES AFFECTED. This publication succeeds the OMEGA Navigation System User Guide, promulgated by the Navy on 1 March 1978.

DISTRIBUTION - SDL No.

	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	z
A	2	2	2	2	2	2		2	2	2			2	2							2					
B	500	100	100	2	2	2	2	2	2	2	2	2	2	2	2	2	100	2	2		2	300				
C	2	2	2	2	2																					
D	2			2									2											50		
E																										
F																										
G																										
H																										

NON-STANDARD DISTRIBUTION:

4. ACTION. Area and district commanders and unit commanding officers shall give this publication appropriate dissemination. Public requests and additional copies of this guide are available through:

Superintendent of Documents
U.S. Government Printing Office
Washington, D.C. 20402
(202) 783-3238

H. H. Kothe

H. H. KOTHE
Captain, U.S. Coast Guard
Acting Chief, Office of Navi

CONTENTS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Cont.)

LIST OF TABLES

INTRODUCTION

This first chapter provides an overview of the OMEGA navigation system and an introduction to this user guide. This introduction is divided into 14 sub-units, each corresponding in name and number to a chapter in this user guide. Each sub-unit consists of a brief synopsis of its corresponding chapter. Reading of the more detailed material in each chapter is encouraged.

Your comments and recommendations for this guide will be appreciated. Please forward your comments to:

Commandant (G-NRN-2)
U.S. Coast Guard
2100 2nd Street, S.W.
Washington, D.C. 20593
TEL: (202) 426-0990

1. SIGNAL FORMAT

OMEGA is a very-low-frequency (VLF), hyperbolic, radionavigation system operating on a time-shared basis, with a total of eight stations transmitting phase-synchronized signals. The VLF band between 9 and 14 kHz has been internationally allocated for OMEGA transmissions. The OMEGA system is designed to provide position-fixing accuracy of 4 nautical miles (nm), 95% of the time for aircraft and ships, continuously and in all- weather.

The OMEGA navigation system was developed by the United States and is being operated in partnership with other nations. The eight permanent OMEGA transmitting stations are located in Norway, Liberia, Hawaii, North Dakota, La Reunion Island (France), Argentina, Australia and Japan. (See Figure 1 and Table 1.)

Table 1. OMEGA Stations

Station	Letter Designation	Coordinates*	Operator
NORWAY	A	66 25 12.62 N 13 08 12.52 E	Norwegian Telecommunication Administration (NTA)
LIBERIA	B	6 18 19.11 N 10 39 52.40 W	Liberian Ministry of Commerce, Industry and Transportation
USA: Oahu, Hawaii	C	21 24 16.78 N 157 49 51.51 W	U.S.C.G.
USA: La Moure, N. Dakota	D	46 21 57.29 N 98 20 08.77 W	U.S.C.G
FRANCE: La Reunion	E	20 58 27.03 S 55 17 23.07 E	French Navy
ARGENTINA	F	43 03 12.89 S 65 11 27.36 W	Argentine Navy
AUSTRALIA	G	38 28 52.53 S 146 56 06.51 E	Australian Department of Transport
JAPAN	H	34 36 52.93 N 129 27 12.57 E	Japanese Maritime Safety Agency (JMSA)

*World Geodetic System 1972 (WGS-72)

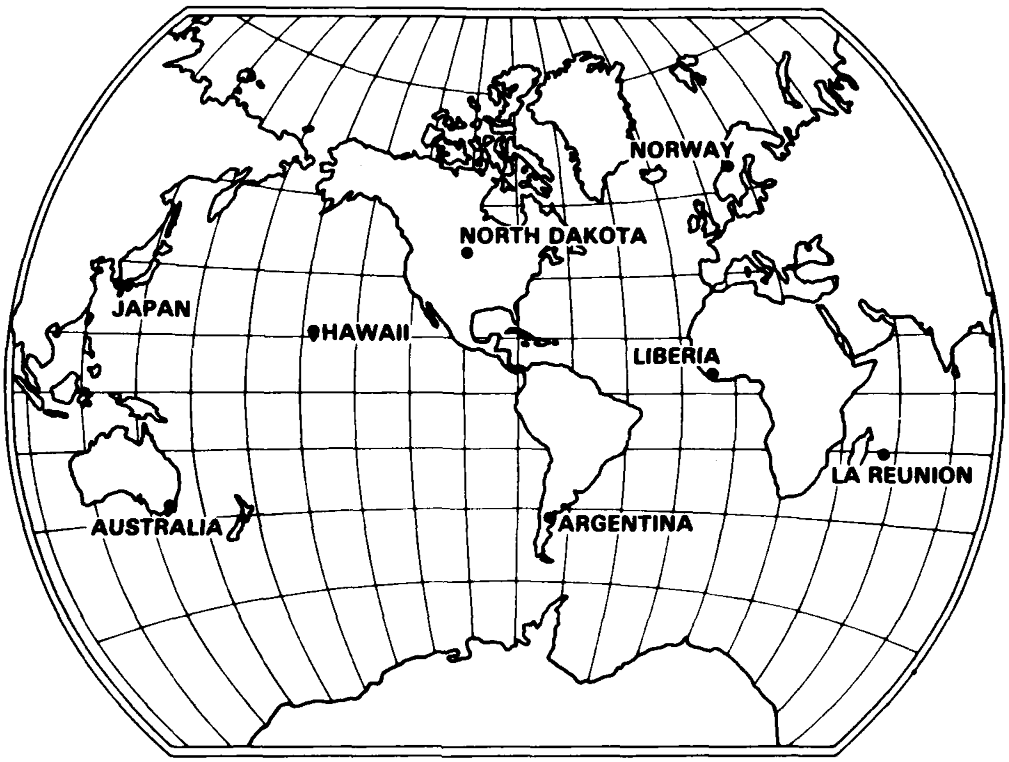


Figure 1. Location of Eight OMEGA Stations

The OMEGA signals from these eight stations are not transmitted simultaneously on the same frequency. If more than one station transmitted the same frequency OMEGA signal at the same time, the receiver would be unable to distinguish one station's signal from another. Therefore, stations must time share these transmissions in a manner which enables a receiver to recognize a particular signal. Each station has a separate time slot in which it transmits five signals of which one navigational signal is at a frequency unique to each station. Four navigation frequencies are common to all stations: 10.2 kHz; 11.05 kHz; 11-1/3 kHz; and 13.6 kHz.

2. SIGNAL SYNCHRONIZATION

For the OMEGA navigation system to operate properly, this precise timing sequence must remain stable. Therefore, each station must maintain synchronization by use of highly stable cesium frequency standards.

3. BASIC CHARACTERISTICS OF THE OMEGA RADIO WAVE

The basis of the OMEGA system is the fact that VLF radio waves exhibit predictable phase stability over extremely long distances to provide nearly worldwide coverage. The accuracy of the system is dependent upon this inherent stability and predictability of the phase variations along the propagation path.

4. TRANSMITTER SIGNAL COMPARISON

OMEGA is configured to permit phase comparisons between synchronized pairs of transmitters. The station pair great circles are shown in Figure 2. The OMEGA signals transmitted according to the format diagram form a family of navigational lanes, which extend as an invisible lattice network worldwide. The orientation of this OMEGA signal grid is precisely established with respect to its position on the earth's surface, although the individual lanes are unidentified. This is analogous to a city in which streets and avenues are sequentially numbered and carefully laid out in a rectangular pattern, but without any street signs.

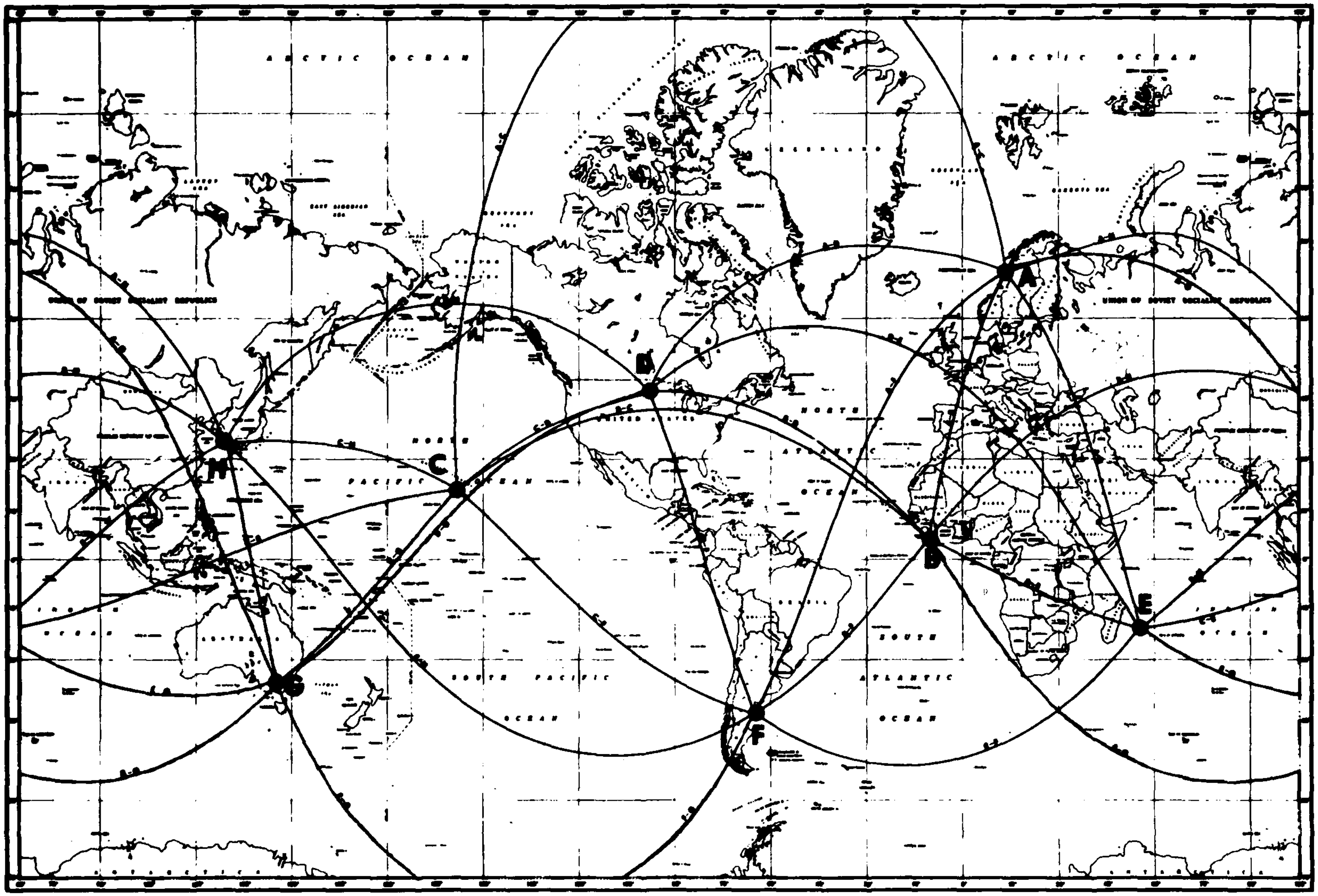


Figure 2. OMEGA Station Baselines

5. LANE IDENTIFICATION

If, in this case you could initially locate yourself at some point within this grid (say the corner of 46th Street and 5th Avenue or half way between 52nd and 53rd Street on 1st Avenue), maintaining a simple count of street and avenue crossings would provide you with a position (street and avenue) update as you moved across the city. The OMEGA receiver compares signals from one pair of stations to establish a navigational lane (or, in our example, an avenue). Reception and comparison of OMEGA signals from a second pair of stations produces a second navigational lane or street. Since one station can be common to both pairs, only three OMEGA stations must be received and analyzed to provide a two line-of-position (LOP) fix. En route, the OMEGA receiver monitors the selected station pairs and keeps track of both the number of lane crossings and the current fraction of lane traversed in order to continuously update LOP information.

6. LANE AMBIGUITY RESOLUTION

Some receivers, which use three or four of the navigation frequencies, automatically perform multifrequency position computations. This enables the receiver to narrow an estimated position from within 144 nm of its true position to within 4 nm. This process is called lane ambiguity resolution.

7. OMEGA PROPAGATION

As previously stated, the OMEGA system depends on the inherent phase stability of VLF radio waves. VLF OMEGA radio waves travel within a wave guide formed by the surface of the earth and the "D" layer of the ionosphere. If the height of the ionosphere above the earth's surface remained stable and the earth's surface was uniformly conductive, the speed and phase propagation of OMEGA radio waves would remain constant and thus very predictable. But this is not the case. The height of the ionosphere changes due to a number of phenomena, some of which are predictable (thus easily compensated for) and others that are unpredictable (these cause random position errors).

8. UNPREDICTABLE CHANGES TO PROPAGATION CONDITIONS

Predictable phenomena, such as day/night/transition, magnetic bearings, ground conductivity and auroral zones, are accounted for in the Propagation Correction tables (PPC). Other phenomena are sudden and unpredictable and are not considered in the PPCs. Modal interference, Sudden Ionospheric Disturbances (SID), and Polar Cap Anomalies (PCA) are all examples of unpredictable irregularities in the phase pattern of the OMEGA signal which can cause position errors of 8 nm.

9. THE OMEGA MONITOR PROGRAM

In an effort to produce more accurate PPCs there is an ongoing program to collect OMEGA signal phase data - the OMEGA Monitor Program. Monitoring consists of measuring the phase of the OMEGA signals with an OMEGA monitor receiver at a fixed location for a minimum of 2 years.

10. THE REGIONAL VALIDATION PROGRAM

Data collected in the OMEGA monitor program is also used in the area validation program. This program assesses regional OMEGA signal coverage, accuracy, and modal interference. As each major oceanic region is validated, a report of the systems operation in that area is issued.

11. THE OMEGA RECEIVER

The modern Lat/Long receiver provides a direct readout of the current latitude and longitude. It also may include such features as navigating using three to four frequencies, automatic selection/deselection of stations based upon computerized maps of station coverage, automatic deselection of modally affected stations based on time of day and location, or multiple frequency fixes to re-establish lane count or to reduce your estimated position from 144 nm to 4 nm.

12. OMEGA NOTICES AND NAVIGATIONAL WARNINGS

A number of ways are used to inform users about OMEGA station off-air periods (either scheduled maintanance or for emergency repairs) or about known propagation disturbances. Notification methods include a 24-hour telephone service, broadcasting radionavigation warnings, and Notices to Mariners and Airmen.

13. OMEGA CHARTS AND PUBLICATIONS

This portion of the Users Guide describes the sources of OMEGA charts and tables, and where to obtain additional information.

14. APPENDICES

Included in the OMEGA Users Guide are four appendices. Appendix A provides the complete series of OMEGA composite coverage diagrams. Appendix B provides a description of the procedure necessary to take a fix with a manual (LOP) receiver (not the newer automatic Lat/Long receiver). Appendix C describes the Differential OMEGA system, which is an accuracy enhancement technique providing fix accuracy to 0.3 nm. Finally, Appendix D is a glossary of terms.

1. SIGNAL FORMAT

The OMEGA signal radiated by each transmitter is a sequence of radio frequency pulses which range in duration from 0.9 to 1.2 seconds and are separated by silent intervals of 0.2 second. The stations timeshare these transmissions in a manner which enables a receiver to recognize a particular station's signals. A pattern of 8 pulses is transmitted over a 10 second interval. Since only one station transmits at a time on any particular frequency, the measurement of relative phase must be made between signal components that are never present simultaneously. A typical pulse sequence is shown in Figure 3. This particular sequence is transmitted by OMEGA station Norway (A). The frequency (in kHz) for each pulse is indicated along with the duration of the pulse in seconds. Four navigation frequencies, 10.2, 13.6, 11-1/3 and 11.05 kHz, are transmitted as shown. It is the comparison of the phase of these signals with those at the same frequencies from other transmitters which establishes the relative position of the OMEGA receiver. In addition, a fifth frequency, unique to each station, is also transmitted. The unique frequency assigned to each OMEGA station is as follows:

Station	Letter Designation	Frequency (kHz)
NORWAY	A	12.1
LIBERIA	B	12.0
USA; Hawaii	C	11.8
USA; N. Dakota	D	13.1
FRANCE; La Reunion	E	12.3
ARGENTINA	F	12.9
AUSTRALIA	G	13.0
JAPAN	H	12.8

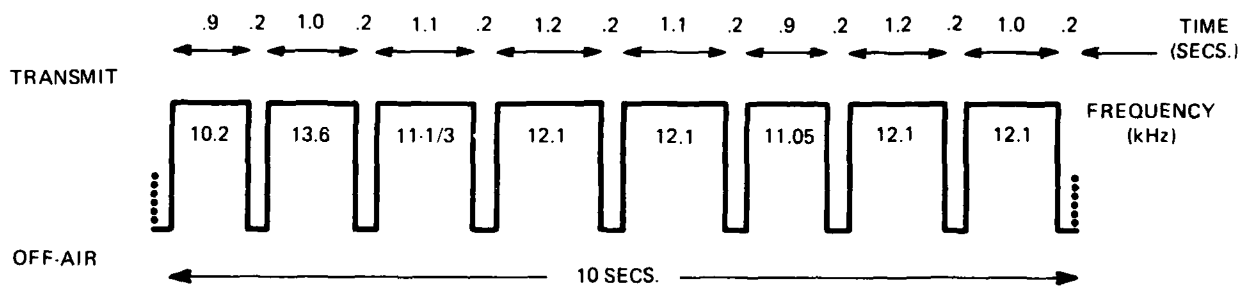


Figure 3. OMEGA Station "A" Signal Transmission Format

The OMEGA signal format from each station is similar in that the frequencies are transmitted in the same format. However, the frequency patterns are staggered to prevent different transmitters from radiating the same frequency simultaneously. Figure 4 shows the complete OMEGA signal transmission format.

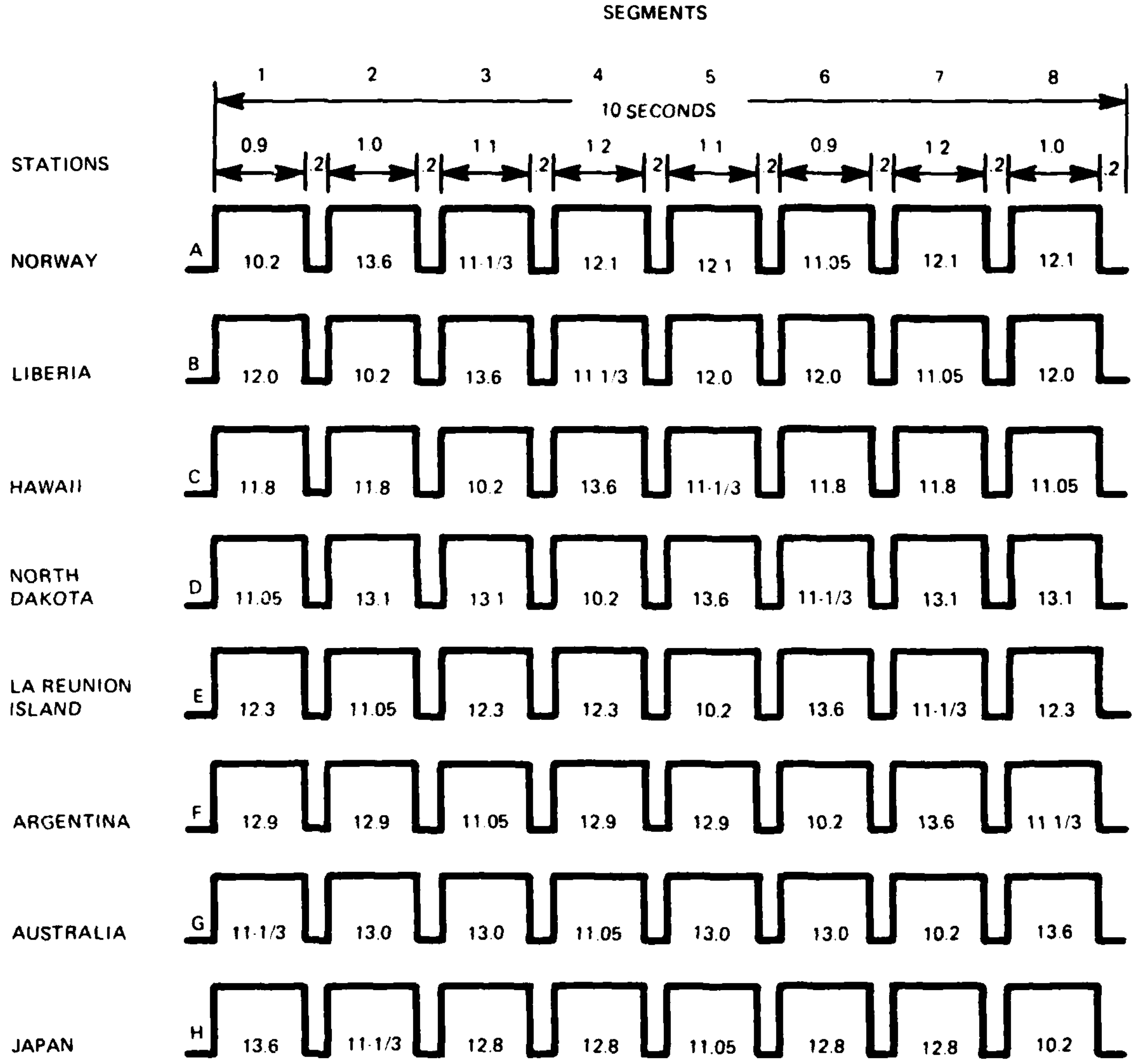


Figure 4. OMEGA Signal Transmission Format

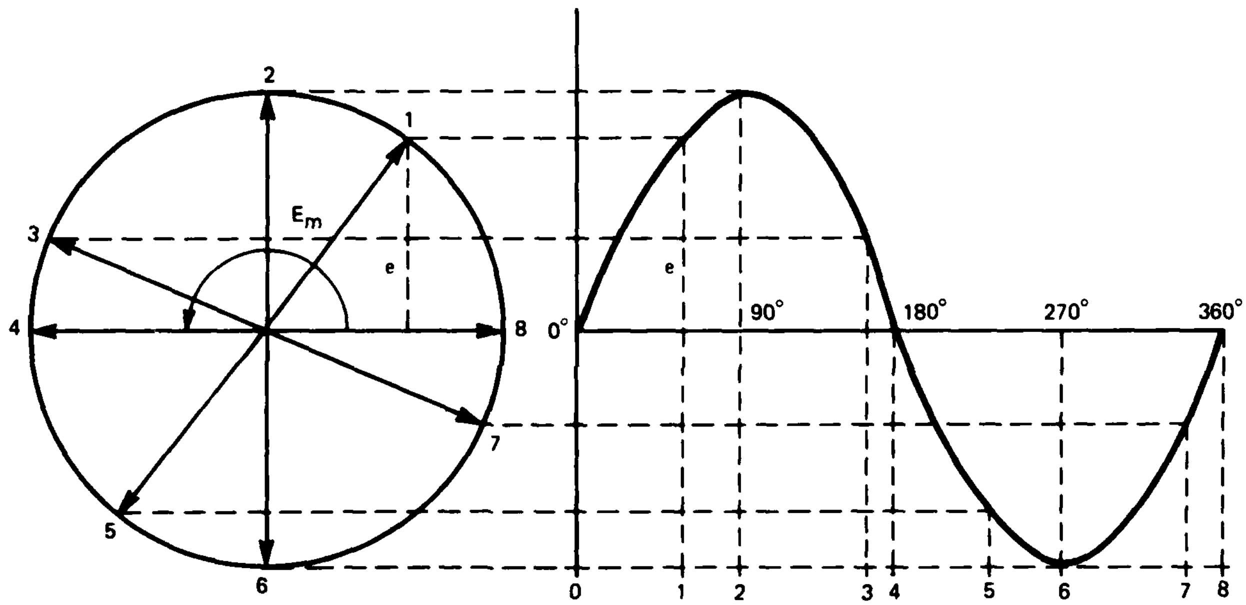
2. SIGNAL SYNCHRONIZATION

Accurate and stable synchronization between the member stations of the OMEGA network is essential to ensure that a station transmits in the exact allotted time interval. This timing sequence ensures constant phase relationships between OMEGA transmissions, thereby keeping the navigation grid stable. Each station uses three cesium frequency standards to ensure synchronization to OMEGA standard time. OMEGA standard time commenced on 1 January 1972 at 0000 hours Greenwich Mean Time (GMT). At that time, the phases of all OMEGA transmissions passed through zero moving in a positive direction. In addition, at that instant in time, OMEGA standard time was coincident with Universal Coordinated Time (UTC). To adjust for the earth's rotation rate, UTC is occasionally changed by 1 second (a Leap Second). OMEGA standard time is not adjusted in this manner as it would cause some users to lose synchronization. Therefore, there are several integral number of seconds between OMEGA standard time and UTC. On July 1, 1983 OMEGA standard time was 12 seconds ahead of UTC. This difference in the time reference is only of importance to receivers which use a time reference to assist in receiver signal acquisition and station capture.

3. BASIC CHARACTERISTICS OF THE OMEGA RADIO WAVE

OMEGA depends on the electromagnetic propagation of precisely timed and sequenced radio-frequency signals. These signals are generated by the currents flowing in the OMEGA station transmitting antenna and spread out in an expanding pattern of circular waves of radio-frequency energy.

The radio signal received from an OMEGA station alternates periodically between positive and negative values at a rate which depends on the frequency of the transmitted signal. The OMEGA signal amplitude varies, in a sine wave pattern, with time (generation of a sine wave is shown in Figure 5). The signal as shown in Figure 6(a) is instantaneously zero at 0 degrees, rising to a maximum positive value at 90 degrees, returning to zero at 180 degrees, to a maximum negative value at 270 degrees and finally back to zero, thus completing a full cycle at 360 degrees. Each succeeding cycle is identical. The frequency of 10.2 kHz (one of four OMEGA navigational frequencies) requires a time interval of 98 microseconds (1 microsecond = 1/1,000,000 second) to complete one cycle. In this example, time = 1/frequency or 1/10200 = 0.000098 second or 98 microseconds.



(a) Revolving Vectors

(b) Generation of Sine Curve

Figure 5. Graphical Representation of a Sine Wave

If a receiver is located at the transmitting antenna, the received signal Figure 6(b) will be "in step" or "in phase" with the signal at the transmitter. However, as the receiver is moved away from the transmitter, the additional time required for the radio waves to propagate to the new location creates a time delay. The delay is 6.1 microseconds per nautical mile of separation, between the signal at the transmitter and the received signal. As shown in Figure 6(c), the signals are no longer in phase. If a very precise reference clock was available at the receiver, this time delay could be measured. The phase difference shown in Figure 6(c) is 1/8th of a complete cycle. At 10.2 kHz this represents a time difference of 12 microseconds. This would suggest that the receiver is approximately 2 nm from the transmitting antenna as shown at radius X in Figure 7. A subsequent increase in the separation of the receiver and antenna will further increase the time delay and the consequent 5/8 cycle phase shift, Figure 6(d). The time delay and phase shift in Figure 6(d)

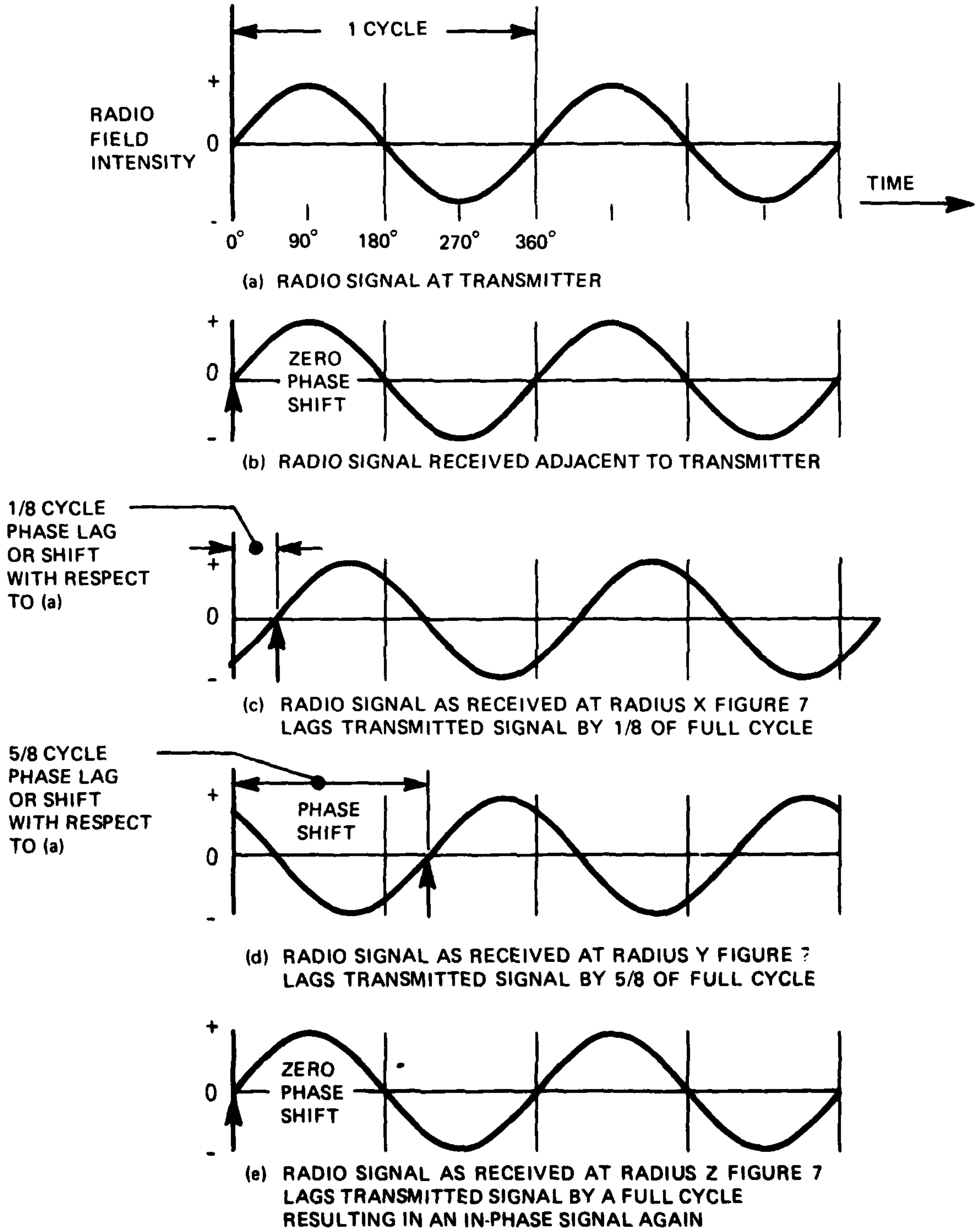


Figure 6. Phase Shift as the Signal Propagates to a Distant Point

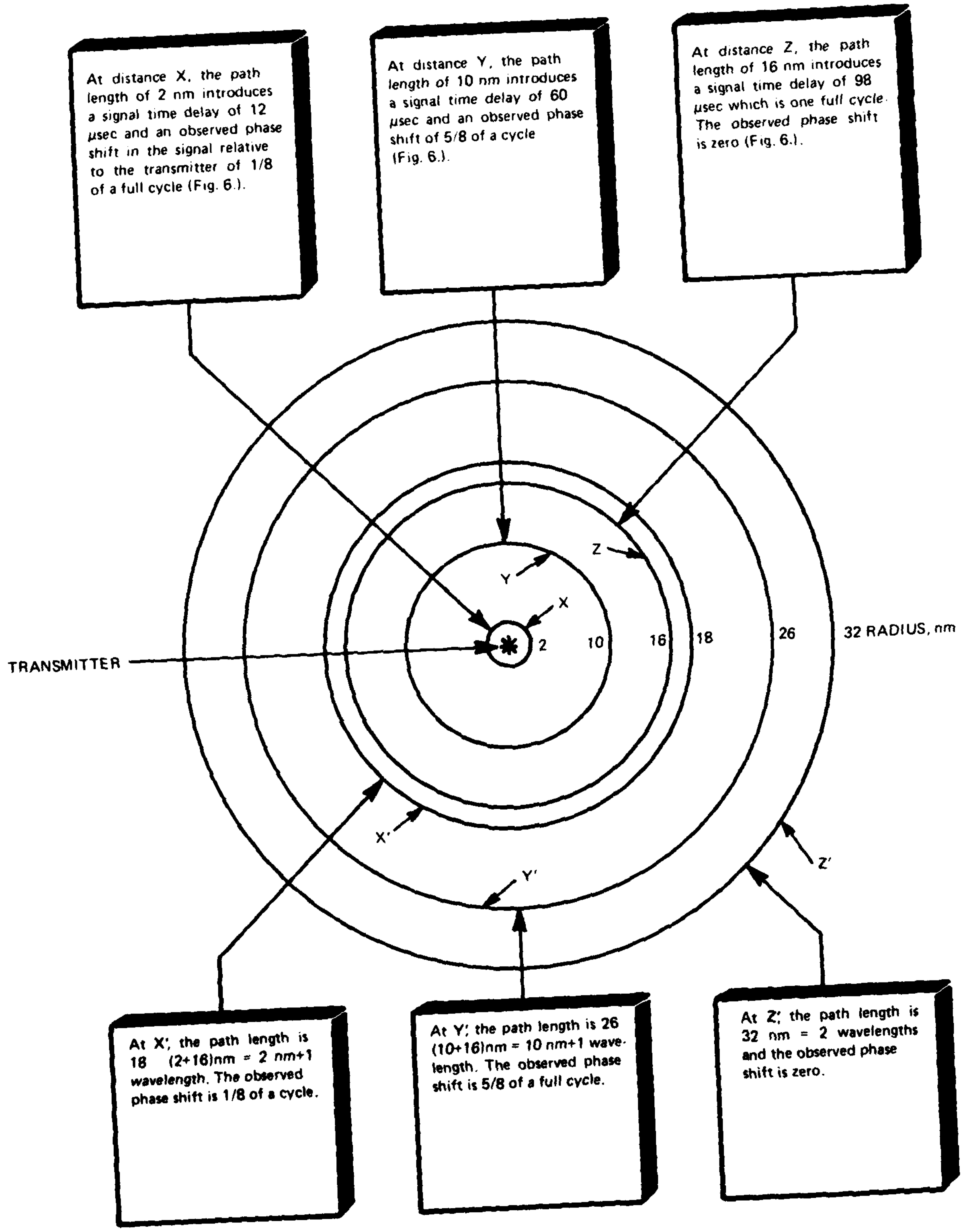


Figure 7. Phase Shift as a Function of Range

represents a distance of approximately 10 nm as shown at radius Y in Figure 7. If the distance were such that the time delay were equal to one complete cycle, (a time delay of 98 microseconds at 10.2 kHz) then the received signal and the transmitted signal would once more be "in step" or "in phase" as shown in Figure 6(e). A radial distance 16 nm from the transmitter represented by this condition is called a wavelength. A wavelength is equal to the distance that a radio wave will travel during the interval represented by one complete cycle. At 10.2 kHz this distance is 16 nm.

Beyond a distance of 16 nm, it is possible to find positions at, for example, 18 nm where the apparent phase is once again only 1/8th of a full cycle. The first 16nm accounts for one complete cycle of wavelength and the 2 nm increment beyond that produces the observed shift of 1/8 of a cycle. From this and the other examples shown in Figure 7, it is evident that this process continues indefinitely. The measurement of the apparent phase shift between the original signal as transmitted and the signal as received, at some point remote from the signal source, is essentially insufficient to determine position location, i.e., it does not disclose the specific whole number of wavelengths in the signal path (this phenomena is called an ambiguity). Only the specific excess fraction of a cycle can be determined.

Any radio signal location method, including OMEGA, which relies on the observation of the relative phase of continuous wave signals for position determination, will encounter this type of ambiguity. An understanding of the circumstances from which lane ambiguities arise and the operating characteristics of the OMEGA navigation system which are provided to resolve them, is recommended for the navigator seeking to use the system to its best advantage under all conditions.

4. TRANSMITTER SIGNAL COMPARISON

To avoid the precise timing requirements involved in the direct measurement of signal phase, OMEGA is configured to permit phase comparisons between synchronized pairs of transmitters. Signals from two transmitters, A and B (Figure 8), are received at point X. The line which connects the positions of transmitting stations A and B is called the baseline of this transmitter pair. The phase of signal A is compared with the phase of signal B and the relative phase shift Δ_{AB} is measured. Since the true time delay in the signals at X is due to the path lengths S_A and S_B, the relative phase between the two signals depends on the difference $S_A - S_B = \Delta_S$. If X moves in such a manner as to keep the value of Δ_{AB} constant, it will trace out a path which keeps Δ_S constant (Figure 9). This path is a hyperbola and is also called a LOP. A hyperbola is described as a curve generated by a point moving so that at any position on the curve, the difference of its distances from two fixed points is a constant value. The OMEGA system is designed for use in the hyperbolic mode. In this mode there is an imaginary vertical line, half-way between stations intersecting the baseline, called the perpendicular bisector. This line contains all the possible locations that are equidistant from two transmitter stations. On either side of this bisecting line, there are hyperbolic LOPs that locate all points where the difference in distance (Δ_S) is constant and the difference in phase (Δ_{AB}) is constant (Figure 10). It takes two transmitter stations to form one LOP and at least three stations to form two LOPs. Two LOPs are required to provide an intersection for a navigation fix. Additional LOPs are located on either side of the perpendicular bisector where the observed phase difference is also Δ_{AB}. However, the Δ_S values for the additional LOPs are greater or less by one or more wavelengths. The spacing along the baseline of these equivalent LOP paths is one half wavelength, which at 10.2 kHz is 8 nm. In an OMEGA receiver, when the phase of signal B is subtracted from the phase of signal A, the result is the algebraic sum of the two signals. If, for example, a receiver had traversed the distance corresponding to half a wavelength (180 degrees), then the receiver would detect a phase difference change of 360 degrees or 0 degrees.

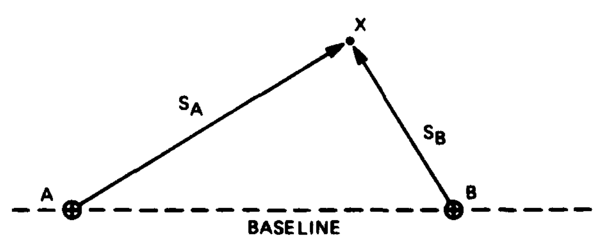


Figure 8. Signals from Two Transmitters Received at a Remote Point

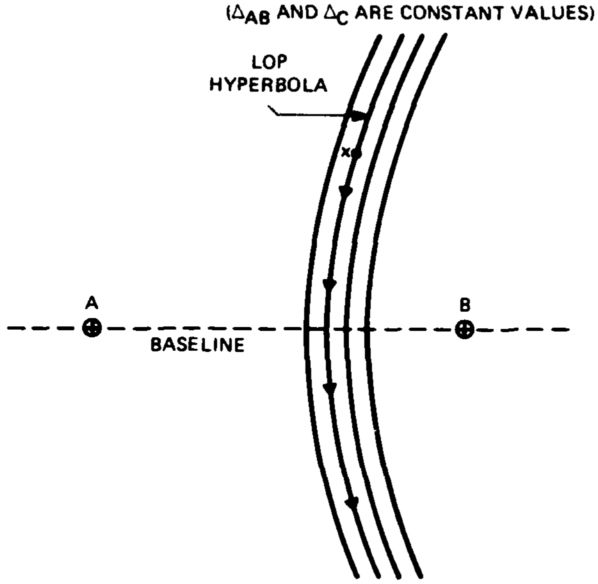


Figure 9. Constant Relative Phase Along One LOP

If a second transmitter pair BC is now considered, a new phase difference measurement Δ_{BC} will provide a new family of LOP hyperbolas symmetric with the BC baseline (Figure 11). The 16 intersections of these two systems of LOP paths (Figure 12) become the possible locations for the receiver. Clearly, at this point, additional information is required to resolve the lane ambiguities and meet the position-finding requirements of the OMEGA user. For this purpose, OMEGA employs the concept of the signal phase lane and the related requirement that at all times the radionavigation receiver will be in operation, it must first be initialized at a known position and then the movement of the vehicle monitored to detect and record lane changes.

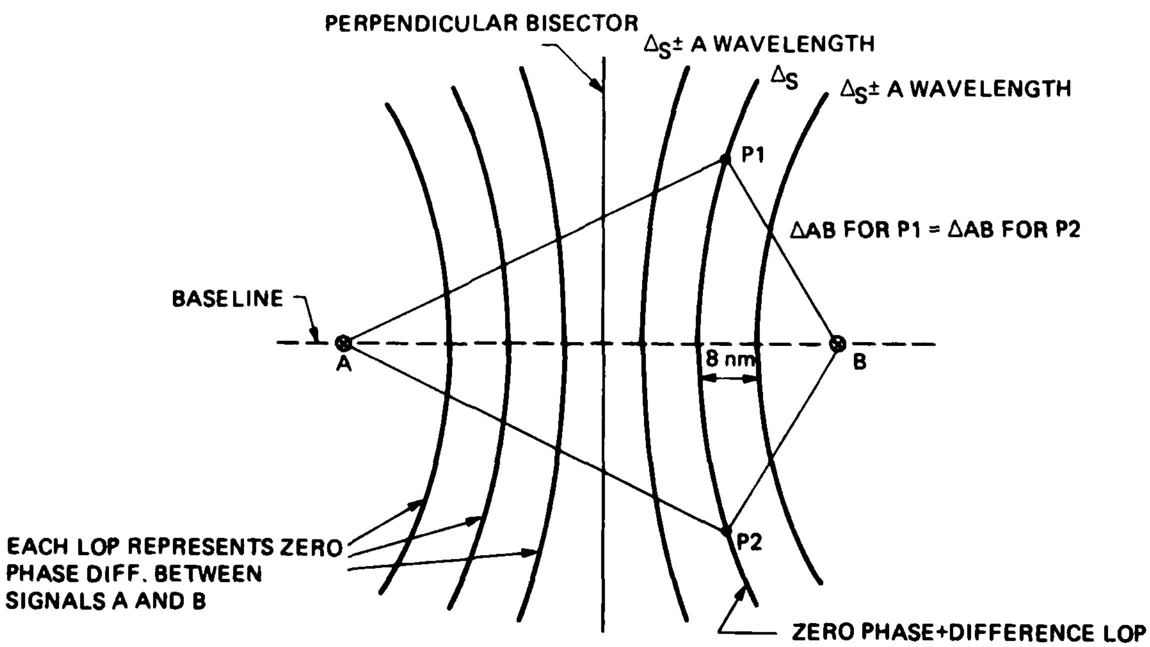


Figure 10. Hyperbolic Configuration

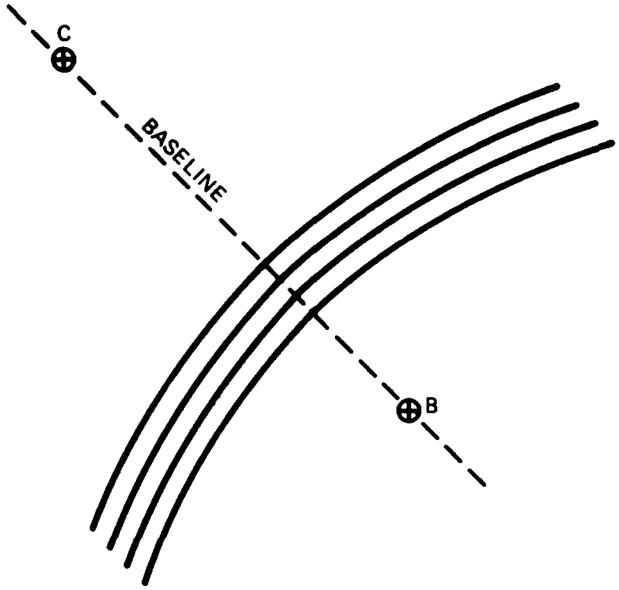


Figure 11. Phase Difference Measurement from Second Transmitter Pair

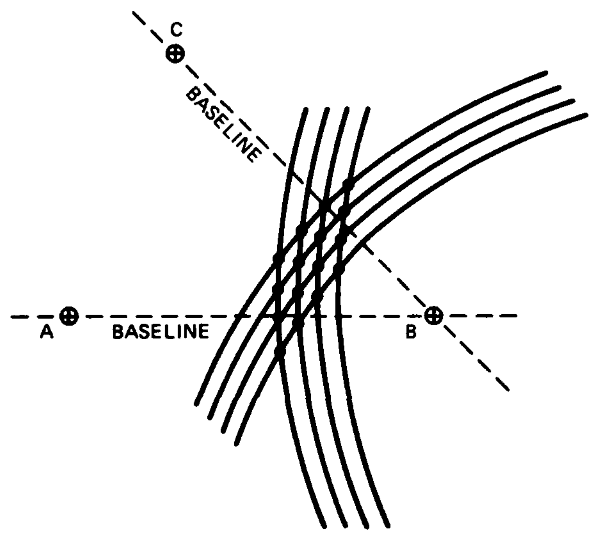


Figure 12. Intersection of Two Systems of LOP Paths

5. LANE IDENTIFICATION

Two identical 10.2 kHz signals transmitted at the same time from stations A and B will meet with zero phase difference at the midpoint (perpendicular bisector) on the baseline. The receiver will detect a phase difference change of 360 degrees or 0 degrees for each half wavelength, approximately 8 nm, in either direction. These zero phase difference points delineate the boundary of a lane. A lane, therefore, can be defined as the distance between consecutive phase difference readings of 0 degrees. For example, this might correspond to a case where Δ_S is equal to 100 wavelengths. There will be a point y adjacent to x where the path difference is 99 wavelengths and where the observed phase difference will also be zero. The path traced out by "y" in maintaining this path difference will also be a hyperbola as shown in Figure 13 where curves for path length differences of 98 and 101 wavelengths are also shown.

These curves represent the location of lines along which the observed phase difference between OMEGA signals from a transmitter pair is zero. At points not on these lines, the phase difference will lie between 0 degrees and 360 degrees. Phase measurements by OMEGA receivers are displayed not in terms of degrees but as a percentage of a lane width. One percent of a lane width is defined as a centicycle (CEC); one lane is comprised of 100 CECs. Note that in Figure 13, receivers at points a,b, and c would measure the same value of phase difference or CECs for station pair AB, but lie in different lanes. The number of CECs can only define a relative position within a lane. It cannot identify the specific lane involved. Movement of the receiver through a lane will provide an indication when a lane boundary is crossed as the phase measurement goes to zero or the CEC value goes to zero.

Maps have been prepared showing the predicted lane boundaries (lines of zero phase differrence or the CEC value of zero) when using a designated OMEGA transmitter pair. These lanes formed by the boundaries are numbered for convenience.

The navigator initializes the OMEGA receiver starting at a known position in a specified lane. Subsequent movement of the ship or aircraft will cause a progressive change in the measured phase differences. Whenever a boundary is crossed (zero phase difference) it is recorded and an accumulated count of such crossings can be used to establish the identity of the currently occupied lane when using the phase difference measurement to determine an LOP.

When combined with a positive identification of the lane, a measured value of an OMEGA station pair

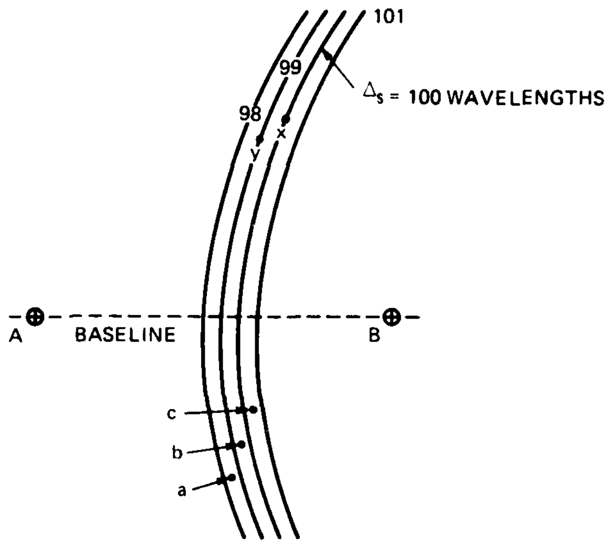


Figure 13. Hyperbolic Lines Representing Particular Wavelengths

phase difference provides a hyperbolic LOP as shown in Figure 14. A second phase difference measurement is made using a different OMEGA station pair, then a second LOP is obtained. This second measurement, using a second station pair, requires that a corresponding initialization, lane identification, and subsequent lane count has been made for phase measurements using this OMEGA pair. The intersection of the two LOPs establishes a position fix.

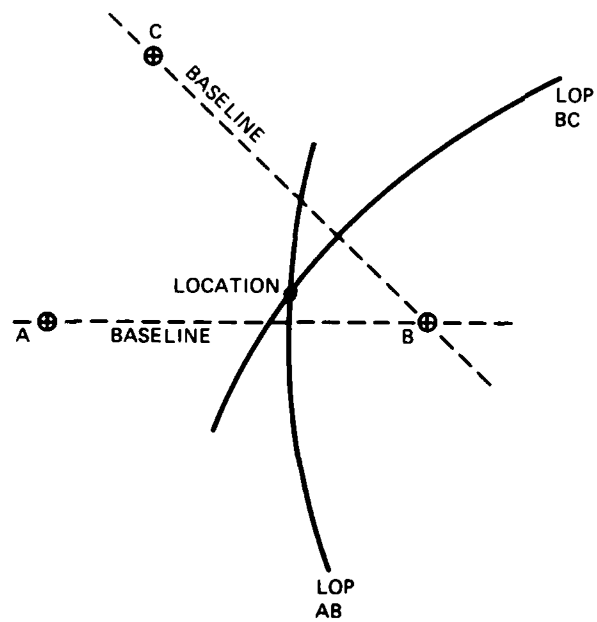


Figure 14. Receiver Location at Intersection of Two LOPs

Some receivers record lane changes using an automatic counter which increments as each zero phase difference is detected. Continuous strip chart recorders of phase difference, graphically displaying the phase shifts and lane boundaries are helpful in determining accumulated lane crossing counts. Other receivers maintain lane counts internally and do not display this information.

For the path taken in Figure 15, the navigator would have noted that the trip started in lane 837 for phase measurements between OMEGA stations A and C and in lane 744 for measurements using OMEGA stations B and C. On arriving at point L, six AC lane boundaries have been crossed putting the vehicle currently in lane AC831, while eight BC lane boundaries have been crossed which corresponds to a position in lane BC736. Note that in this example the direction of the phase change as a lane is crossed (i.e., the phase either increases or decreases) determines whether the change in lane number is up or down.

6. LANE AMBIGUITY RESOLUTION

Lane identification, as described in the preceeding section, is essential for the resolution of the ambiguity of LOP values based on a phase measurement. Lane count can be lost due to power interruptions, operator error, atmospheric disturbance or inability to detect lane crossings during ship or aircraft maneuvers. To reset the lane count, using only the 10.2 kHz OMEGA signal, requires a knowledge of the receiver position within 4 nm. Where position information of this accuracy is not available, it is possible to use the 10.2 kHz signal in conjunction with the 13.6 kHz signal to establish the lane count. It will be shown that this method of combining phase information, on the two OMEGA frequencies plus the difference frequency, has the effect of providing significantly wider lanes. This process is called heterodyning.

Figure 16 is a plot of lane boundaries which exist for phase measurement on a designated OMEGA transmitter pair. The boundaries are shown for comparison of the phase difference between the

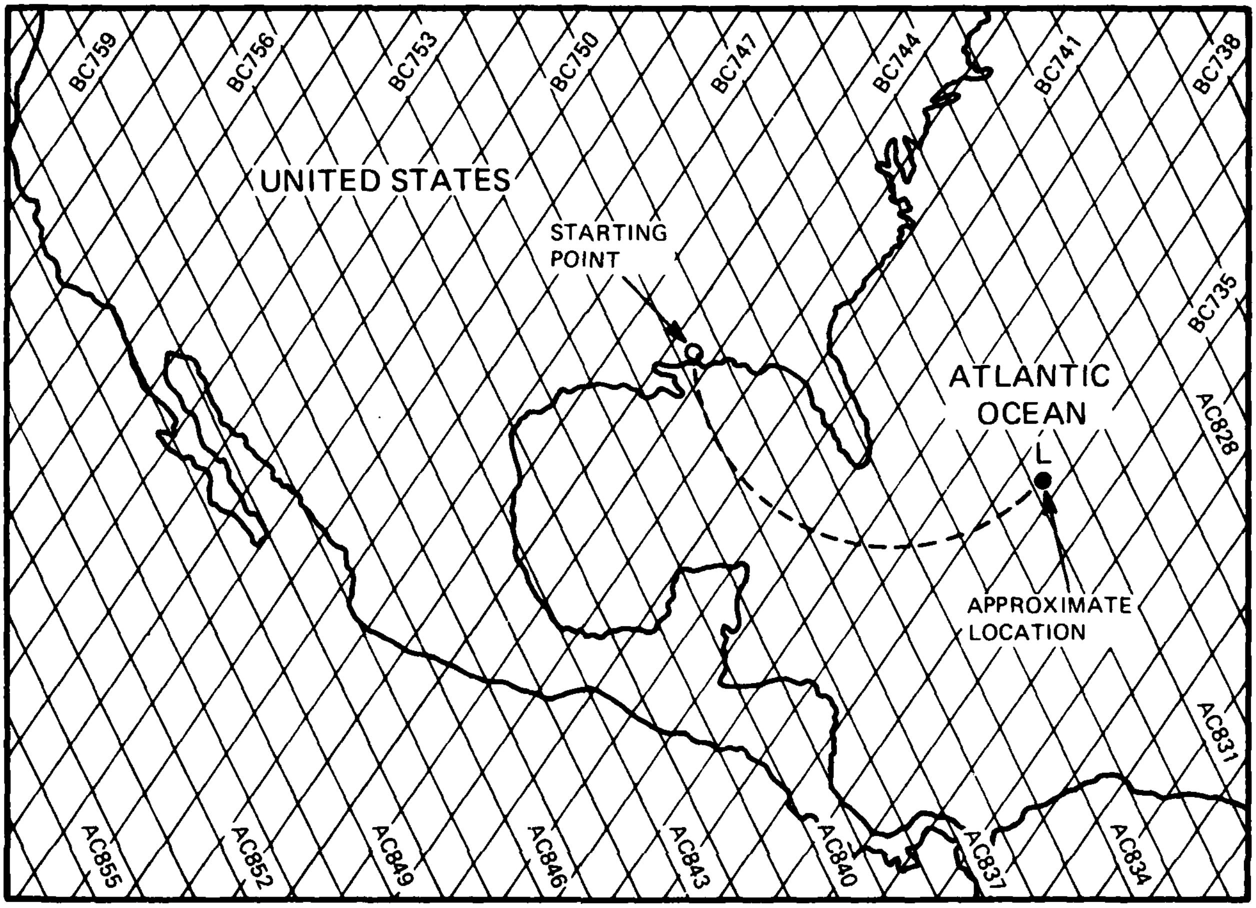


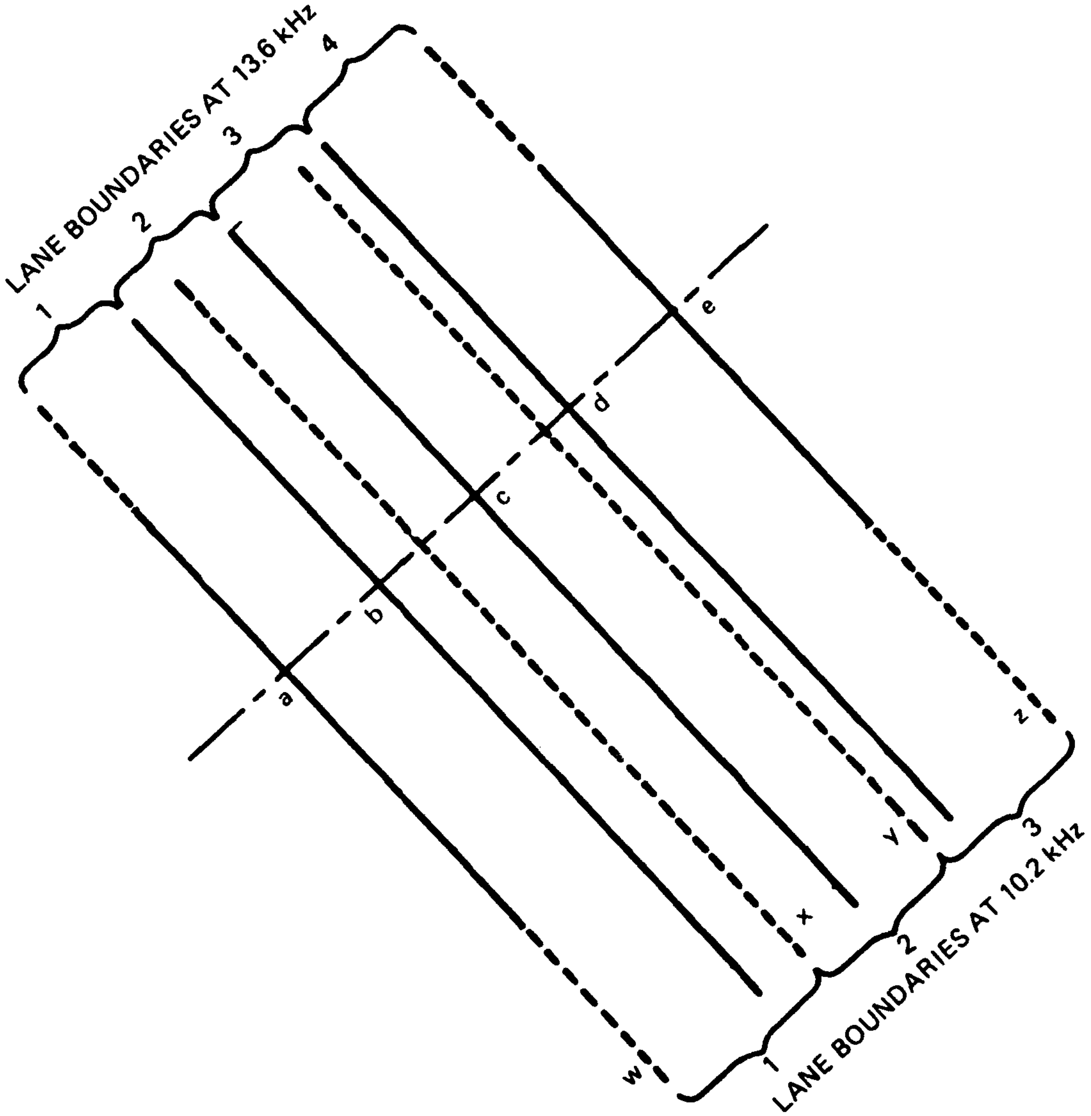
Figure 15. Lane Identification Based on Known Starting Point

10.2 kHz signal from each transmitter and for the phase differences between the 13.6 kHz signal from each transmitter. Note that the zero phase shift lines for both the 10.2 and 13.6 kHz signal coincide at points "a" and "e". There are three 10.2 kHz lanes between points "a" and "e" and four 13.6 kHz lanes. This is due to the 4/3 ratio in the wavelengths of the two signals. The phase difference which would be measured by a receiver moving along the line "a" to "e" (a distance of 24 nm) is plotted in Figure 17 where Figure 17 (a) is the phase difference of the 13.6 kHz signals and Figure 17 (b) is the phase difference of the 10.2 kHz signals.

Now suppose, for example, that a receiver moving from left to right somewhere between "w" and "z" measured a phase difference of 10 CECs (10% of the lane width) for the 10.2 kHz signals. The three possible lane locations between "w" and "z" which would correspond to such a measurement are indicated in Figure 17(b) at the points marked with a large dot.

If it is assumed you have lost lane count and have an estimated position with an error of greater than 4 nm, the 10.2 kHz phase measurement can not be resolved, thus the correct lane can not be identified with only the 10.2 kHz signal. A second measurement at 13.6 kHz gives a phase difference of 50 CECs (50% of the lane width) and this provides four possible receiver locations shown in Figure 17(a). This lane ambiguity also can not be resolved using only 13.6 kHz.

While the individual frequency phase measurements can not resolve the problem of lane identifi-



Four lane boundarias for zero phase difference at 13.6 kHz are indicated by a solid line and designated a, b, c, d, and e.

Three lane boundaries for zero phase difference at 10.2 kHz are indicated by a dotted line and designated w, x, y, and z.

Note: The zero phase difference condition coincides at both boundary a and w, and boundary e and z.

Figure 16. Lane Boundaries for Two OMEGA Frequencies

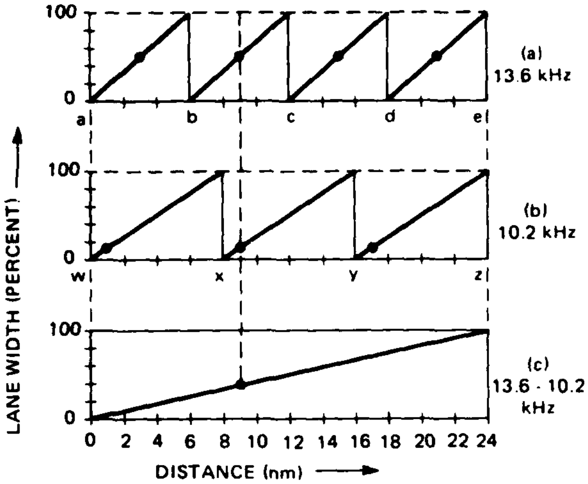


Figure 17. Relative Phase Shift

cation, a comparison of the two sets of possible receiver positions shows there is only one position which will satisfy both measured values, i.e., lane "x" and "y" of Figure 17 (c).

The general application of this technique can be seen if the phase values observed along path "w" to "z" for the 10.2 kHz signals are subtracted from those observed for the 13.6 kHz signal at the same positions. This results in the linear plot shown in Figure 17(c), starting from 0 at the "w" lane boundary and increasing to 100 at the "z" lane boundary. If this is compared with the phase change across the lanes observed at 10.2 and 13.6 kHz, it can be seen that taking the difference between the two phase measurements has created an OMEGA signal lane that is 24 nm wide (Figure 17c). Using our previous example, the phase difference between the 13.6 and 10.2 kHz signals is (50-10) or 40 CECs. This would locate the receiver at a point 40 percent of the lane width to the right of the zero point and corresponds to our previous position identification.

Preliminary use of this wider lane information derived from two-frequency phase measurements will identify the correct 10.2 kHz lane location and the counter can be reset to the correct lane. The only requirement for the use of this method is that the estimated position must be known within ±12 nm since this combination lane will repeat at 24 nm intervals. Similarly, a wider lane simulation can be created by comparing phase difference measurements at 10.2 kHz and 11-1/3 kHz. This will give an effective lane width of 72 nm, requiring the estimated position to be known within ±36 nm. Likewise, a combination of the 11- 1/3 kHz and 11.05 kHz signals will provide a lane width of 288 nm requiring the estimated position to be known only within ±144 nm.

7. OMEGA PROPAGATION

Long-range radio communications and navigation systems such as OMEGA depend on the existence of the ionosphere, which is located in the upper atmosphere at altitudes between 40 and 150 nm. This is a region of electrically charged particles created and maintained by the influence of high energy solar and cosmic radiation in the atmosphere. At frequencies below 50 MHz, the ionosphere acts as an irregular mirror, bending and reflecting radio waves back to the earth's surface. As shown in Figure 18(a), the propagation of radio signals over long distances takes place along a path between the earth and the ionosphere. The actual distance traversed by the radio signals in moving from the transmitter to a receiver depends on the height to which the signal penetrates the ionosphere before being reflected. At high frequencies (HF) and medium frequencies (MF), the reflective properties of the ionosphere are variable over a wide range and subject to only approximate estimates. At VLF, reflections occur at the bottom of

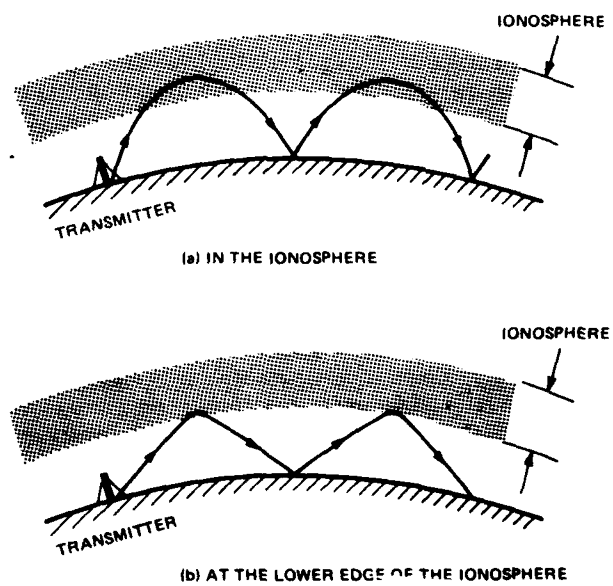


Figure 18. Multiple Reflection and Bending of Radio Signals

the ionosphere. Extensive experience and detailed propagation studies have demonstrated that in the case of OMEGA signals, the reflection heights are relatively stable. As a consequence, the cumulative phase delay of the signal in moving from the transmitter to the receiver location can be predicted with considerable accuracy under normal conditions.

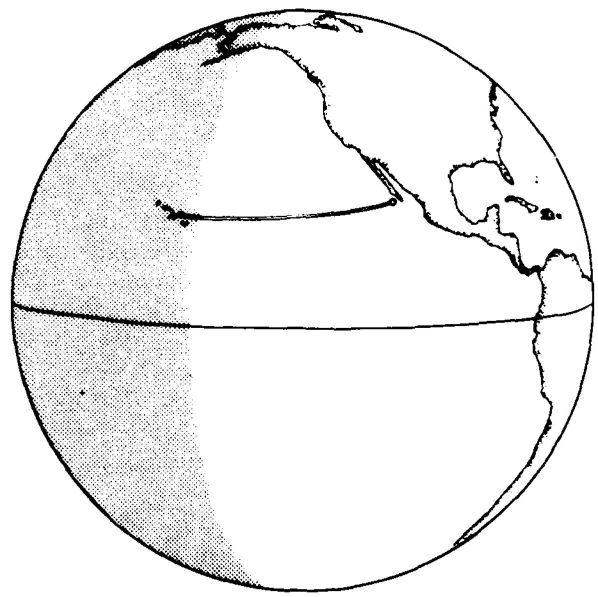
Since the ionosphere is created, in part, by the action of solar radiation, the day and the night ionospheres differ significantly in height and the density of charged particles. As the earth rotates, the ionosphere undergoes a regular periodic change from daytime equilibrium conditions to nighttime conditions. Along the sunrise and sunset lines there exists a transition region as the charge density increases at sunrise and decreases at sunset. The reflection height in the daytime for OMEGA signals is approximately 43 nm.

For a daytime path, where both the transmitter and receiver are in the daytime hemisphere, the signal path phase shift can be predicted to an equivalent of ±5 CECs. At night, the reflection height increases to 55 nm and prediction accuracies for all night side signal paths are reduced to ±10 CECs. Signal paths for which the sunrise or sunset line lies between the receiver and transmitter encounter an additional loss in prediction accuracy. This effect is known as transition. If the signal path is on a generally north-south line (Figure 19) the transition period is of short duration. Due to the rapid transition, accuracy is poor during the transition period. For a generally east to west signal path (Figure 20) the transition interval is much longer and the prediction error is less due to the gradual phase changes caused by the longer transition periods.

The propagation phenomena which affect the quality of the OMEGA signals for navigation purposes on a regular and predictable basis are incorporated into the Propagation Correction (PPC) tables. Examples of predictable phenomena are: Daytime/Nighttime ionosphere height changes and the location of the sunrise/sunset line with respect to the location of the transmitter and receiver. Signal paths which will be affected by modal interference are also indicated in the PPC tables; these paths should be avoided. Additional information about PPC tables can be obtained in the OMEGA charts and publications section.

RECEIVER: N. ATLANTIC
TRANSMITTER: LIBERIA
NORTH-SOUTH PATH: SHORTER TRANSITION INTERVAL; LESS FIX ACCURACY

Figure 19. Transition on North/South Path



RECEIVER: BAJA CALIFORNIA
TRANSMITTER: HAWAII
EAST-WEST PATH, LONGER TRANSITION INTERVAL; MORE FIX ACCURACY

Figure 20. Transition on East/West Path

8. UNPREDICTABLE CHANGES TO PROPAGATION CONDITIONS

Sudden and dramatic modifications in the normal ionosphere brought about by solar storms are not predictable either in terms of time or duration of occurrence or in terms of impact on OMEGA signal path lengths. These propagation disturbances fall into three general classes: Sudden Ionospheric Disturbances (SID), Polar Cap Anomalies (PCA), and Modal Interference.

A SID occurs when X-rays are emitted from the sun during a solar flare. This added ionizing radiation causes a lowering in the effective height of the ionosphere over the illuminated sunlit area. This changes the OMEGA signal paths. A SID may cause LOP errors of 4 nm or more at 10.2 kHz on the baseline of sunlit paths. These disturbances form in a matter of minutes after a solar flare begins and last from 45 minutes to 3 hours. Due to the short duration of a SID, navigational warnings are not issued.

The PCA influences the ionosphere at high latitudes and is caused by the emission of high energy protons from the sun. These protons are concentrated in the polar regions by the earth's magnetic field and also cause a reduction in the height of the ionosphere. This affects the phase of transpolar OMEGA signals. The PCA occurs within a few hours after the appearance of a solar flare and usually last from 1 to 3 days and may cause positional errors of up to 8 nm at 10.2 kHz on the baseline for long transpolar paths. Irregular propagation disturbances can not be taken into account in the OMEGA system. OMEGA notices or navigational warnings are issued by various means on the occurance of PCAs.

A third type of interference is modal interference. The areas and time intervals subjected to modal interference are generally predictable, but the effects are not.

Modal interference causes irregularities to appear in the phase pattern of the OMEGA signal. Ideally, one propagation mode would be completely dominant at all times, and the resultant phase grid would be stable. In practice, competing modes do not completely disappear and three situations are recognizable: if the competing mode is very small, the dominant mode will establish a nearly regular phase pattern, as intended; this is usually what happens. A second possibility is the competing mode may be almost equal to the dominant mode. The third, and most serious case is that in which modal dominance changes. This may occur, for example, if one mode is dominant during the day and a second mode is dominant at night. Clearly, sometime during sunset and sunrise, the transitional period, the two modes must be equal. Depending upon phasing of the modes at equality, abnormal transitions may occur in which lanes are "slipped" or lost. LOP errors of 8 nm or more at 10.2 kHz on the baseline are possible under such conditions. Use of the affected station should be avoided. PPC table corrections in areas of predicted modal interference are shaded gray to warn about unreliable fixes during the times and in the areas indicated. Alternate OMEGA stations should be used. Some automatic OMEGA receivers are programmed to automatically deselect OMEGA stations during predicted periods of modal interference.

9. THE OMEGA MONITOR PROGRAM

Accurate PPC tables and computational algorithms are necessary to properly use the OMEGA navigation system. In order to determine accurate PPCs, OMEGA signal phase data is needed from locations all over the world and for all times of the year. This data is collected using OMEGA monitor receivers.

Monitoring consists of measuring signal phase with an OMEGA receiver at a fixed location for a minimum of 2 years. A typical installation consists of one OMEGA monitor receiver, one recording device (magnetic cassette tape), and one 8-foot whip antenna, antenna coupler, and antenna cable. The receiver is fully automatic, requiring only initial setting of desired parameters, a daily check to ensure the receiver is properly operating, and monthly replacement and mailing of the magnetic cassette tape to the OMEGA Navigation System Operations Detail (ONSOD). Figure 21 depicts the location of the OMEGA monitor receivers.

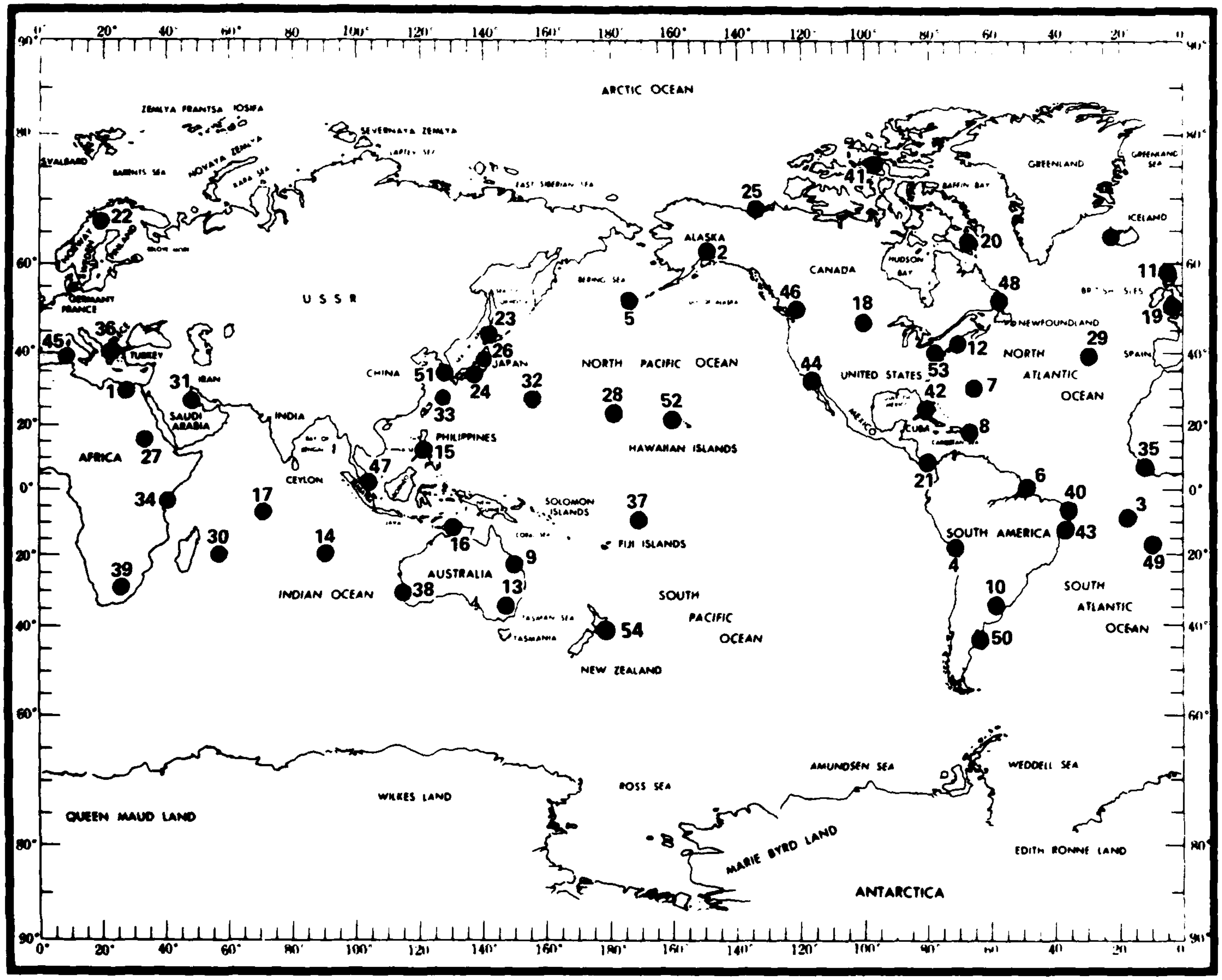


Figure 21. OMEGA Monitor Station Locations

The following is a list of the monitor locations as of April 1983:

OMEGA MONITOR SITE LOCATIONS

1. Alexandria, Egypt	29. Lajes, Azores
2. Anchorage, Alaska	30. La Reunion Island, France
3. Ascension Island, U.K.	31. Manama, Bahrain
4. Arequipa, Peru	32. Marcus Island, Japan
5. Attu, Alaska	33. Miyakojima, Japan
6. Belem, Brazil	34. Mombasa, Kenya
7. Bermuda, U.K.	35. Monrovia, Liberia
8. Borenquin, PR	36. Nea Makri, Greece
9. Brisbane, Australia	37. Pago Pago, American Samoa
10. Buenos Aires, Argentina	38. Perth, Australia
11. Butt of Lewis, U.K.	39. Pretoria, South Africa
12. Cambridge, Massachusetts	40. Recife, Brazil
13. Canberra, Australia	41. Resolute Bay, NWT, Canada
14. Cocos Islands, Australia	42. Richmond, Florida
15. Cubi Pt., Phillipines	43. Rio de Janeiro, Brazil
16. Darwin, Australia	44. San Diego, California
17. Diego Garcia, U.K.	45. Sardina, Italy
18. Dickey, North Dakota	46. Seattle, Washington
19. Farnborough, London, U.K.	47. Singapore, Malaya
20. Frobisher Bay, Canada	48. St. Anthony's Island, Canada
21. Galeta Island, Panama	49. St. Helena Island, U.K.
22. Hestmona, Norway	50. Trelew, Argentina
23. Hokkadio, Japan	51. Tsushima, Japan
24. Ibu-oshim, Japan	52. Wahiawa, Oahu, Hawaii
25. Inuvik, Canada	53. Washington, DC (2)
26. Kasumgaseki, Japan	ONSOD
27. Khartoum, Sudan	Naval Observatory
28. Kure Island, Hawaii	54. Wellington, New Zealand

10. THE REGIONAL VALIDATION PROGRAM

One of ONSOD's primary functions is to determine OMEGA signal coverage and accuracy parameters. This is a big task due to the global extent of the OMEGA system and the influence of diurnal, seasonal, and solar cycles. Since these parameters are varied, they must be examined and studied using a large number of sensors and techniques. The primary source of information is the fixed monitor network which provides signal phase data and estimates of signal-to-noise ratio at precisely known sites. OMEGA signal phase data collected at monitor sites serves as the basis for updating the semi-empirical propagation model used to generate PPCs. To lend an actual operational aspect to theoretical coverage and accuracy assessments ONSOD developed a system validation concept for various regions of the globe. The system validation concept, takes data from aircraft and shipboard measurements and the final monitor network and uses it to validate existing models. Both scientifically controlled and operational reports prepared by navigators are taken into account. The end result of system validation is a readjustment of present signal coverage assessments; a better definition of PPC errors, which assist in their improvement; a statement of coverage and accuracy in the validation region; and more precisely defined regions of modal interference.

The OMEGA data collection schedule for system validation purposes is as follows:

Area Report	Validation Flights	Final Report
North Atlantic	1978	1980
North Pacific	1979	1980
South Atlantic	1980	1983
Indian Ocean	1983	1984
South Pacific	1984	1985
Western Pacific	1985	1986
Mediterrean Sea	1986	1987

As each major oceanic sector is calibrated and validated, ONSOD issues a report of the system's operational adequacy, background, validation methodology, data description, classification and analysis. Reports are made availalbe to the public through the National Technical Information Service (NTIS) located in Springfield, Virginia.

11. THE OMEGA RECEIVER

An LOP receiver requires that the navigator using propagation tables and OMEGA plotting charts first correct and then interpret the receiver readouts. This process is described in detail in the section on OMEGA FIX (Appendix B).

The LAT/LONG receiver automatically interprets the OMEGA signal information and provides a direct readout of current LAT/LONG coordinates.

There are several basic operating requirements which are common to all OMEGA receivers. These requirements are the capability to:

a. Select one or more OMEGA frequencies and reduce, by appropriate filtering, the intrusion of background radio noise of either man made or natural atmospheric origin.

b. Identify, through controlled sequential switching, the source station of the various signal frequencies as they are received.

c. Measure the relative phase of the OMEGA navigation signals received from designated station pairs.

Since phase measurements must be accomplished indirectly, each receiver must contain a stable frequency standard and each navigation frequency used is compared in turn to this internal reference. The receiver frequency standard is also used to control the synchronous switching required to decode the OMEGA station format.

If the receiver is a simple LOP model, the display provides lane count and fractions of a lane for each selected station pair corresponding to the current position of the receiver. A LAT/LONG receiver will have added computational and control capabilities in addition to memory storage of propagation correction tables. The conversion from lane identification and lane position to receiver latitude and longitude is automatically provided by the LAT/LONG receiver.

The most sophisticated receivers will have the capability of tracking a large number of stations. The processor pairs stations after considering optimal geometry, signal strength, modal interference, and other factors. This allows for automatic selection of the optimum pair to use for position finding plus re-acquisition of lane count when signals are lost.

11.1 Airborne OMEGA Receivers

The speed and distances travelled by an aircraft require receivers with rapid response times. Therefore, manual adjustments to the receiver must be minimized. A typical airborne OMEGA navigation system consists of a control display unit, a receiver-processor unit and an antenna coupler unit. Airborne OMEGA receiver systems vary in price depending on their sophistication and aircraft requirements, but average $40,000 each. Their average weight is approximately 30 pounds.

The technique of rate aiding is common to all airborne receiver designs. Since the OMEGA transmission format extends over a 10 second period, each phase is artificially advanced (or rate-aided,) so that all phases appear to have been received simultaneously. Without this procedure the motion of the aircraft would cause position errors due to differences in time of receipt of the phase of a signal from different stations. Heading and speed information are also entered into the receiver automatically as the basis for rate aiding.

As a pre-flight procedure, the operational status of transmitting stations and the possibility of any unusual ionospheric activity affecting signal transmissions should be determined.

In summary, the airborne OMEGA navigation receiver is intended for use in those portions of the global airspace where OMEGA meets required en route accuracies. OMEGA performs well for over-water flights and in flights over unimproved areas.

An airborne OMEGA receiver typically consists of the following equipment:

Control Display Unit

The control display unit is the principle link between the pilot and the navigation system. This unit is used to apply system power, enter date, time, present position, waypoints and display various navigation data outputs.

Receiver Processor Unit

The receiver processor unit contains most of the system electronics. It processes signal inputs from the antenna coupler unit and other sensors and provides navigation outputs which are displayed on the control display unit. Propagation correction tables and coverage diagrams are incorporated into the airborne automatic receiver just as in the marine LAT/LONG receiver. To initialize the receiver, the approximate starting position, GMT and date are entered. The receiver then proceeds to determine its current position and to thereafter navigate with little operator involvement. Unless there are unusually strong interference signals from local or radio noise sources, OMEGA receivers can be initialized within a few minutes.

Antenna Coupler Unit

The antenna coupler unit consists of an antenna and an integral active signal amplifier.

There are two types of airborne antennas in general use. The most common antenna is the orthogonal loop, which receives and amplifies two components of the signal's magnetic field. This design is relatively immune to interference from precipitation static. Prior to the installation of a loop antenna, a magnetic survey is made of the outer surface of the aircraft to locate a mounting position free from magnetic noise interference. If such a spot cannot be found, the alternative use of a capacitive (E-field) antenna must be considered. Although the E-field antenna is immune to magnetic noise effects, it does suffer from interference due to precipitation static.

An important consideration in the selection of an OMEGA receiver for position finding is the required tracking and/or recovery rates. Station pair lanes in the vicinity of the baseline are typically 8 nm wide (for the 10.2 kHz signal). At aircraft speeds, this results in a rapid transition in lane count as compared to surface vehicle speeds. Airborne OMEGA receivers require a design which provides both fast tracking and rapid response rate. Since the OMEGA signal format provides updated navigational information only on a 10 second cycle, it is necessary in some cases to assist the OMEGA receiver to hold its lane identification by projecting changes on the basis of vehicle velocity and heading.

11.2 Marine OMEGA Receivers

The marine OMEGA receivers range in price from $5,000 to $10,000 depending upon the degree of sophistication and ease of operation desired by the user. The weight of a marine OMEGA receiver averages 60 pounds. Marine receivers generally use a whip antenna with a coupler assembly. Most marine receivers have the following basic characteristics:

a. Display/readout resolution - 0.01 lanes (1 CEC);

b. Operating frequency - 10.2 kHz standard; other frequencies optional;

c. Synchronization - manual, semi-automatic, or fully automatic; and

d. Internal battery for emergency backup power.

The marine OMEGA receiver typically uses an 8-foot stainless steel or fiberglass whip antenna which is connected to the receiver via an impedance matching coupler. The whip antenna is usually attached directly to the coupler. The coupler is then connected to the receiver via a convenient length of cable.

The proper installation of the antenna and ground in any OMEGA navigation receiver is very important. The basic 10.2 kHz transmitted signals of the OMEGA system fall within a band of frequencies where electrical noise is prevalent. In addition, 10.2 kHz is the 170th harmonic of the 60 Hz power line frequency and the 204th harmonic of the 50 Hz power line frequency.

Noise from other electronic equipment, such as radio or radar, should be avoided as it may cause signal overload damage. Interference generated onboard by ignition, compressors, power generators, and the like should also be avoided. The antenna should be located where it will be well away from any electrical noise generated onboard. Generally, the higher the location of the OMEGA antenna, the better. Although height does not significantly affect the received amplitude of a distant signal, additional height does tend to place the antenna farther away from (and thus reduce the effect of) the ships electrical noise.

The antenna should be mounted vertically. However, angled or horizontal mounting is permissible if required, although some loss of sensitivity will occur. In addition, the antenna location should not be adjacent to metallic guy wires which may tend to re-radiate electrical noise into the OMEGA antenna. The length of the cable connecting the antenna to the receiver is not critical, although there may be a maximum length limitation. Adequate cable length should be used to make a correct installation without having to splice the cable. Even though most cables are shielded, it is a good installation practice to avoid putting the cable in with other ship wiring in order to reduce the possibility of electrical noise pick-up.

12. OMEGA NOTICES AND NAVIGATIONAL WARNINGS

A number of methods are employed to advise OMEGA users of particular information about the OMEGA system such as station off-air periods and propagation disturbances.

A telephone answering device, number (202) 245-0298 located at ONSOD, Washington, DC, has a recorded status announcement which is updated as system changes occur. If additional information is required, ONSOD may be reached at (202) 245-0837. ONSOD also originates a message that is used to advise selected government users of OMEGA system status changes. The Defense Mapping Agency Hydrographic/Topographic Center (DMAHTC) is one of the recipients. DMAHTC is responsible for providing official notification of status changes for all U.S. navigation systems to both public and private marine users. They, in turn, will issue a HYDROLANT/HYDROPAC message and/or a NAVAREA IV/XII message.

Radio Navigational Warnings issued by the DMAHTC are broadcast from the stations listed below.

HYDROLANT warnings are transmitted from Naval communication stations at:

Station	Time	Frequency
Norfolk, VA	0800-0900	8090, 12135, 16180 kHz, A1
	1700-1800	8090, 12135, 16180, 20225 kHz, A1
Key West, FL	0800-0900	5870 kHz, A1
	1700-1800	5870, 25590 kHz, A1
Thurso, Scotland	0800-0900	7504.5, 12691 kHz, A1
	1700-1800	7504.5, 12691 kHz, A1
Rota, Spain	0800	5917.5, 7705 kHz, A1
	1500	5917.5, 7705 kHz, A1
	1700	5917.5, 7705 kHz, A1
	2200	5917.5, 7705 kHz, A1
Nea Makri, Greece	0800-0900	4623, 13372.5 kHz, A1
	1700-1800	4623, 13372.5 kHz, A1

NAVAREA IV warnings are transmitted from Naval communication stations at:

Norfolk, VA	1500-1600	8090, 12135, 16180, 20225 kHz, A1
	2200-2300	8090, 12135, 16180, 20225 kHz, A1
Key West, FL	1500-1600	5870, 25590 kHz, A1
	2200-2300	5870, 25590 kHz, A1

HYDROPACS are transmitted from Naval communication stations at:

Guam	0100-0200	4955, 8150, 13380, 21760 kHz, A1
	0800-0900	4955, 8150, 13380, 21760 kHz, A1

Station	Time	Frequency
San Miguel	0100-0200	8506, 10440.5, 122000 kHz, A1
Phillipines	0800-0900	8506, 10440.5, 122000 kHz, A1

NAVAREA XII warnings are transmitted from the Coast Guard communications station at:

Honolulu, HI	0300	4525, 9050, 13655, 16457.5, 22472 kHz, A1
	1700	4525, 9050, 13655, 16457.5, 22472 kHz, A1

For additional information read DMAHTC Pub 117A and 117B. The notation, A1, indicates telegraphy without the use of a modulating audio frequency (i.e., by on-off keying).

At 16 minutes past each hour, the National Bureau of Standards Station WWV (Fort Collins, Colorado) broadcasts a message concerning the status of each OMEGA station, signal anomalies, and other appropriate OMEGA information. At 47 minutes past each hour WWVH (Hawaii) broadcasts similar information. These broadcasts are on 2.5, 5.0, 10, 15, and 20 MHz.

Time-critical aeronautical information which is of either a temporary nature or is not sufficiently known in advance to permit publication on aeronautical charts or in other operational publications, receives immediate dissemination via the National Notice to Airmen (NOTAM) Service, a telecommunications system. NOTAM-D information is distributed automatically by the National Communications Center to predetermined address listings, of both local and distant air traffic facilities. All facilities have immediate access, upon request, to NOTAM-D information on file in the National Communication Center computer data base via the NOTAM telecommunications system.

An integral part of the NOTAM System is the biweekly NOTAM (Class II) publication. Class II refers to the fact that the NOTAMs appear in printed form for mail distribution as opposed to Class I NOTAMs which are distributed via telecommunications. The first part of the NOTAM consists of notices which meet the criteria for NOTAM-D and are expected to remain in effect for an extended period.

The National Flight Data Center will issue NOTAM text upon receipt of OMEGA information from ONSOD.

The Airman's Information Manual and the United States of America Aeronautical Information Publication (AIP) provide more information on this topic.

The Notice to Mariners is published to advise mariners of important matters affecting navigational safety. Information for the Notice to Mariners is contributed by the following agencies: DMAHTC (Department of Defense) for waters outside the territorial limits of the United States; National Ocean Survey (Department of Commerce) for surveys and charting of the coasts and harbors of the United States and its territories; the U.S. Coast Guard (Department of Transportation) for the safety of life at sea and the establishment and operation of aids to navigation; and the U.S. Army Corps of Engineers (Department of Defense) for the improvement of rivers and harbors of the United States.

In addition to the notices on unplanned OMEGA station off-air periods, the navigator should know that major planned station maintenance normally takes place in the months listed for each station:

November	-	Australia
February	-	Liberia
March	-	Argentina
June	-	La Reunion
July	-	North Dakota
August	-	Norway
September	-	Hawaii
October	-	Japan

Planned off-air times are normally publicized 4 to 6 weeks in advance. They may vary in length from a few days to several weeks, depending on the extent of maintenance or repairs required. Every effort is made to hold off-air periods to an absolute minimum during these months.

13. OMEGA CHARTS AND PUBLICATIONS

13.1 Charts

The principal U.S. organization responsible for producing and distributing OMEGA navigational charts and tables is the DMAHTC, located in

Brookmont, Maryland. This government agency is tasked with producing navigational products for areas outside of U.S. domestic waters, for both military and civil use. The National Ocean Survey (NOS), National Oceanic and Atmospheric Agency in Rockville, Maryland, is tasked with providing charts for civil use, but only within U.S. domestic waters. The following paragraphs summarize actual or planned chart production by these agencies:

DMAHTC

OMEGA Plotting Charts - DMAHTC has completed 114 charts in the 76-7700 Series. In addition, 12 charts covering the polar regions have been published. These are small scale charts of approximately 1:2,188,000 scale.

International Hydrographic Organization (IHO) International Charts - DMAHTC has completed 47 charts in this series. The scale for the series is at 1:3,500,000.

Standard Nautical Charts - Many U.S. charts containing navigational and bathymetric information contain OMEGA lattice overlays. Most of these are listed in DMAHTC Publication 1-N-L and are identified with a suffix (OMEGA). Their scales are 1:300,000 or smaller.

National Ocean Survey (NOS)

This agency began production of nautical charts with OMEGA lattice overlays (scale 1:300,000 and smaller) for U.S. coastal waters in 1980.

13.2 Propagation Correction Tables

The navigator using an OMEGA LOP receiver must apply a correction for the propagation delay from each station caused by diurnal and seasonal changes. The navigator using a manual receiver must obtain these corrections from a series of tables. The only agency currently producing the correction tables is the DMAHTC.

For indexing purposes, the world has been divided into 26 areas. Originally, corrections were computed for the 10.2 kHz frequency and the 3.4 kHz difference frequency (heterodyning). The 3.4 kHz corrections have been discontinued and 13.6 kHz corrections substituted. Newer correction tables shade those corrections in areas of predicted modal interference. This gray shading warns the navigators that such OMEGA stations may give unreliable fixes if used during the specified times.

13.3 Lattice Tables

The lattice tables allow the navigator to plot lines of position on standard nautical charts (scales smaller than 1:300,000) within an OMEGA lattice overprint. Selected station pairs, based on best crossing angle and gradient are computed for each table area. There are currently 249 lattice tables in the distribution system. An average of six pairs are available for each table area.

OMEGA propagation correction tables and hyperbolic lattice tables carry the Publication Series number 224 and are so indexed in DMAHTC Pub. No. I-N-A, Catalog of Nautical Charts, (Miscellaneous and Special Purpose Navigation Charts, Sheets and Tables). Nautical charts overprinted with the OMEGA lattice are indexed in the Regional Catalogs (Pubs. 1-N-1 through 1-N-9).

The tabular data has been subdivided and arranged so that the OMEGA PPC Table series will be printed, distributed, and made available for each individual station, enabling the navigator to acquire only the stations and areas desired. The publication number together with the suffix and station letter will fully identify the table for requisitioning purposes.

A standard phase velocity is used for each chart (propagation velocity changes are accounted for in PPC tables), and only the basic 10.2 kHz frequency LOPs are printed. LOPs for other frequencies can be derived from this basic frequency. Additionally, lattice tables are being produced for the navigator, who can then construct his own LOPs on any plotting sheet or chart desired. Instructions for the lattice tables are provided in the introduction to the tables.

Inquiries for charts and publications may be made to:

Defense Mapping Agency
DMA Office of Distribution Services
Warren Building
6101 MacArthur Blvd.
Brookmont, MD 20315
Tel: (202) 227-3048/49

14. APPENDICES

APPENDIX A: COMPOSITE COVERAGE DIAGRAMS

Appendix A contains the OMEGA Navigation System 10.2 kHz coverage prediction diagrams (Figures A-1 through A-16). The 16 diagrams show the global distribution of 10.2 kHz signals at 2 different received signal-to-noise levels for 8 fixed diurnal and seasonal times of year. One criterion is a signal-to-noise ratio (SNR) of ≥ -20 db in a 100 Hz bandwidth, while the second criterion specifies SNR of ≥ -30 db. In addition to the SNR requirements, the coverage diagrams assume that the modal interference induced phase deviation ($\Delta\phi$) in the signal relative to the reference signal must be no greater than 20 CEL.

The composite coverage diagrams display the global accessibility of usable 10.2 kHz signals from all OMEGA stations at selected times.

In each diagram, the combination of signals that can be accessed in a region is indicated by the set of letters within the contours enclosing the region. For example, the diagram in Figure A-1, the expected coverage in Iceland, is from station A, B, D, F, and H. Some regions display a number indicating the number of signals that can be received in that region. Each coverage contour is labeled with a station designator and an arrow in the direction of the accessibility of the usable signal from the labeled station. The region around the Norway Station (A) in Figure A-1 is labeled with a 6. Coverage in that region is from stations B, C, D, E, F, and H. Some diagrams show a shaded area which contains at least three usable signals, but whose geometric dilution of precision causes unacceptable position fix error.

NOTE: The diagrams assume the radiated power of each station to be 10 kw.

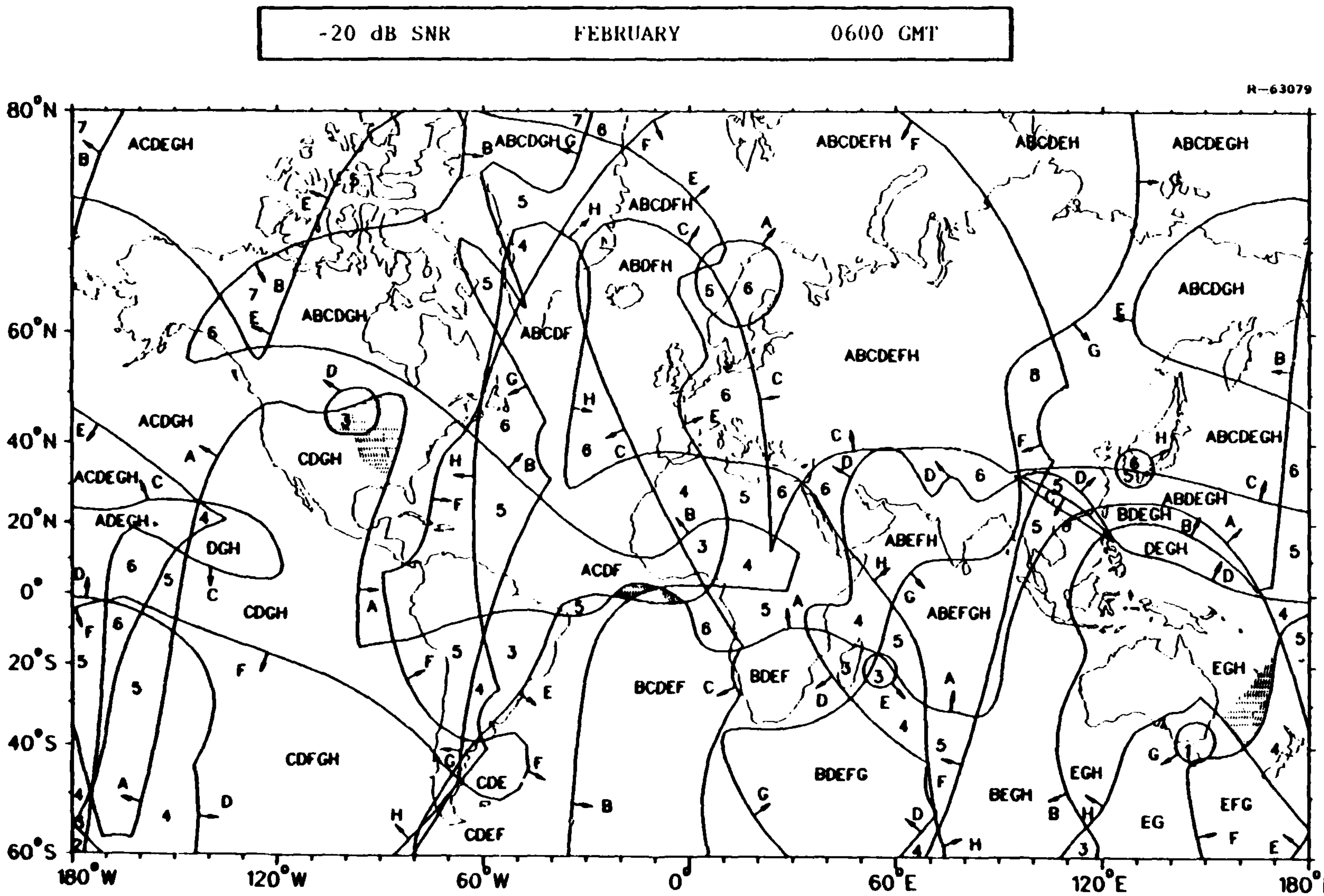


Figure A-1. OMEGA Composite Coverage Diagram (-20db, Feb., 0600 GMT)

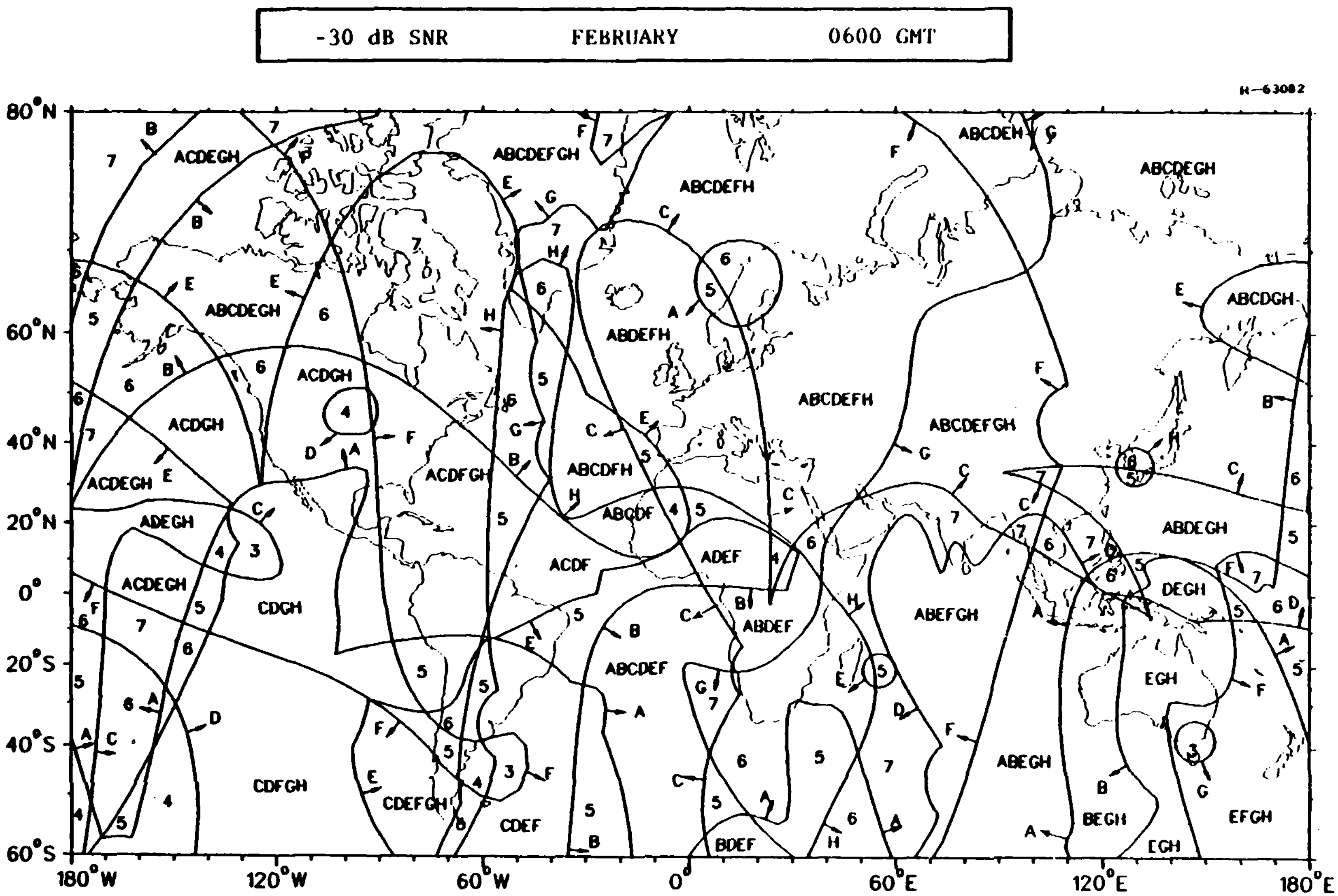


Figure A-2. OMEGA Composite Coverage Diagram (-30db, Feb., 0600 GMT)

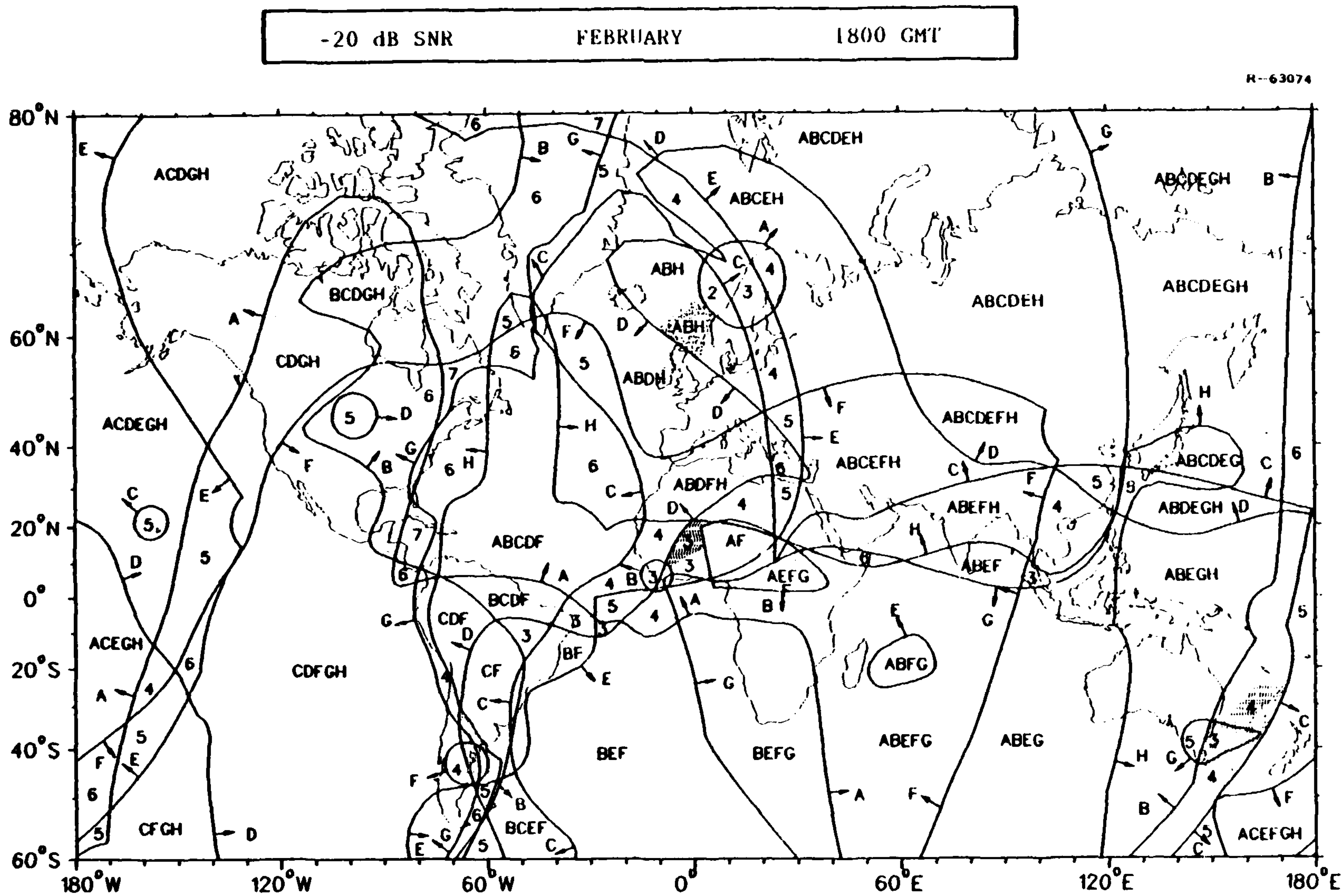


Figure A-3. OMEGA Composite Coverage Diagram (-20db, Feb., 1800 GMT)

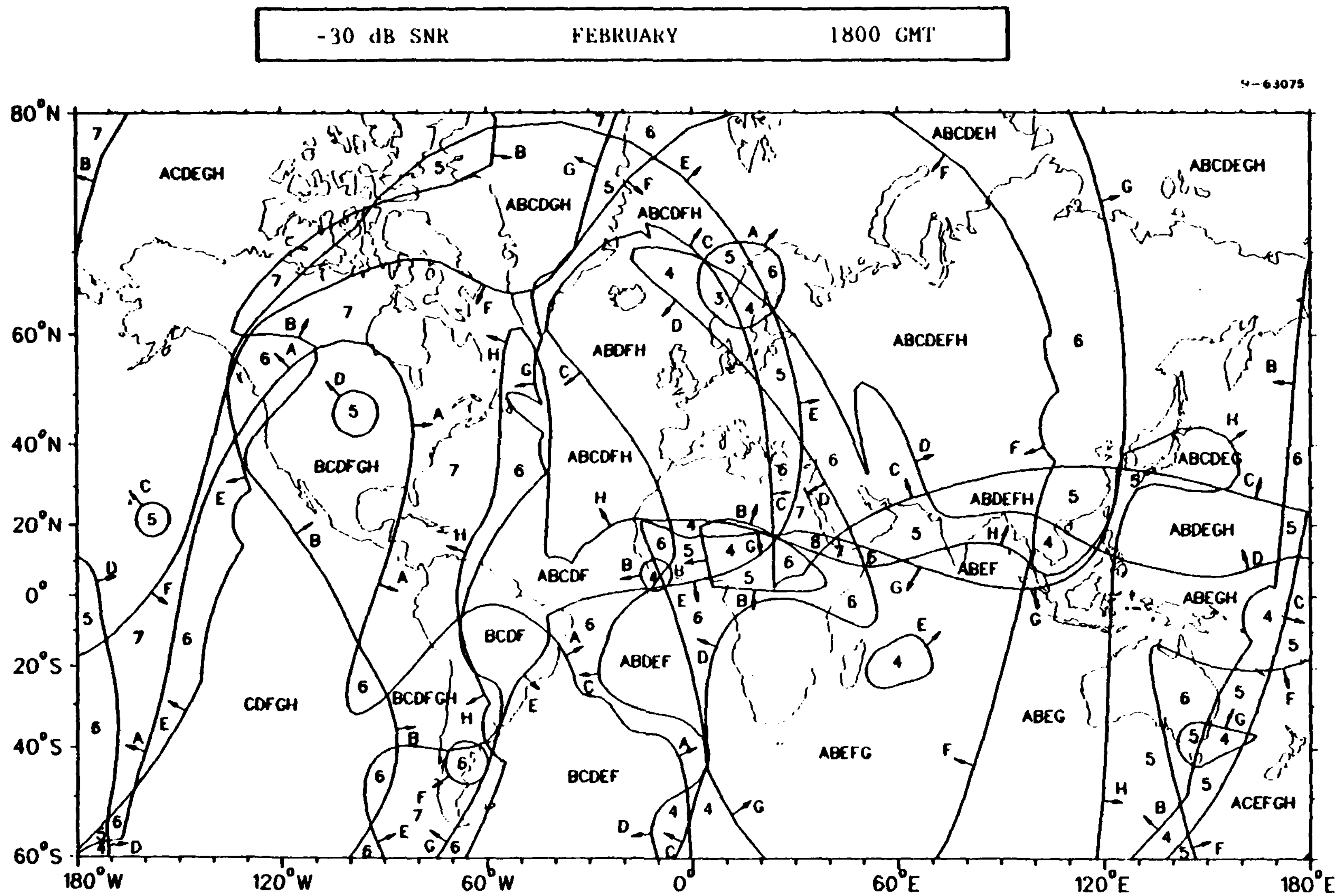


Figure A-4. OMEGA Composite Coverage Diagram (-30db, Feb., 1800 GMT)

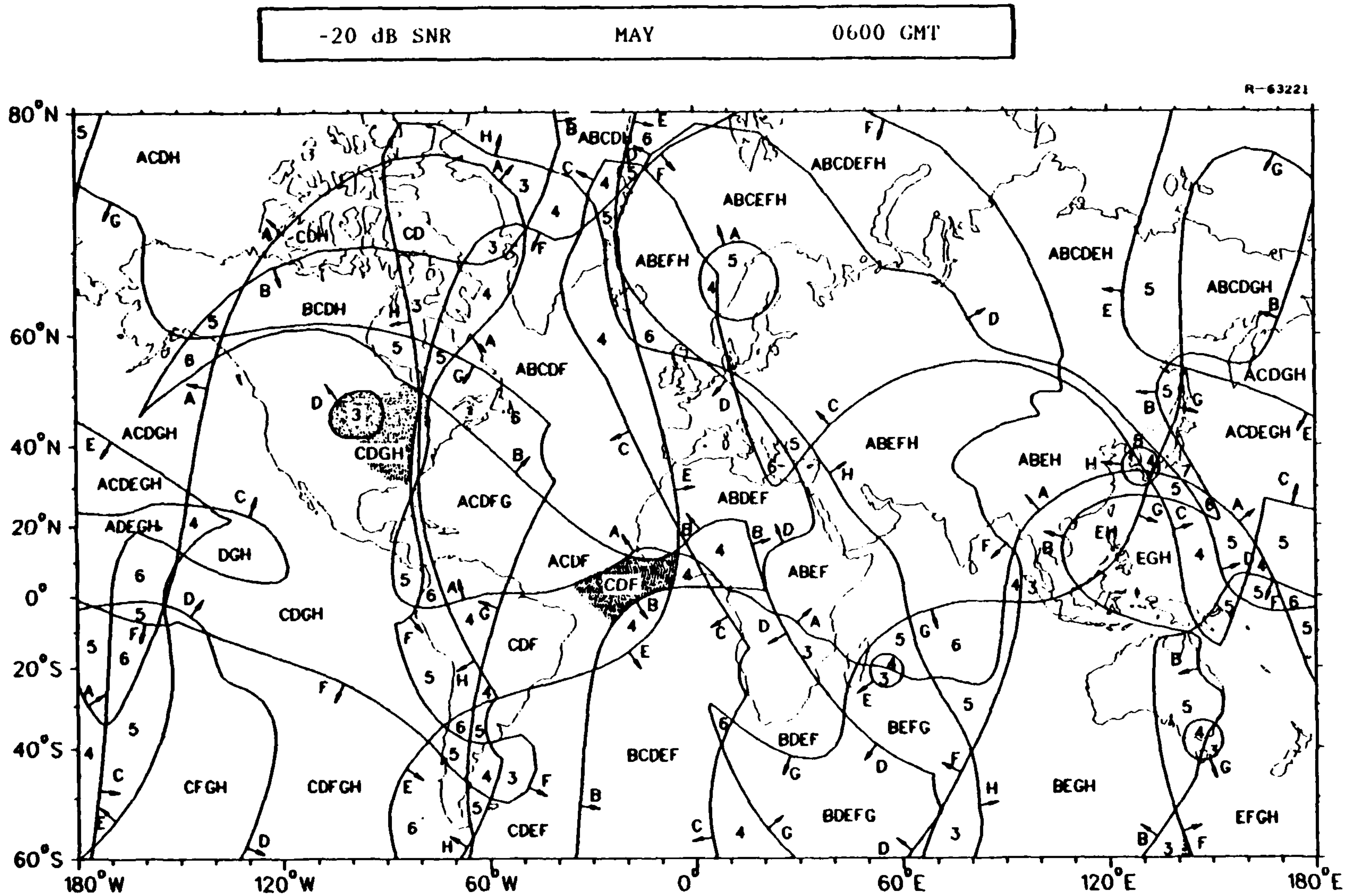


Figure A-5. OMEGA Composite Coverage Diagram (-20db, May, 0600 GMT)

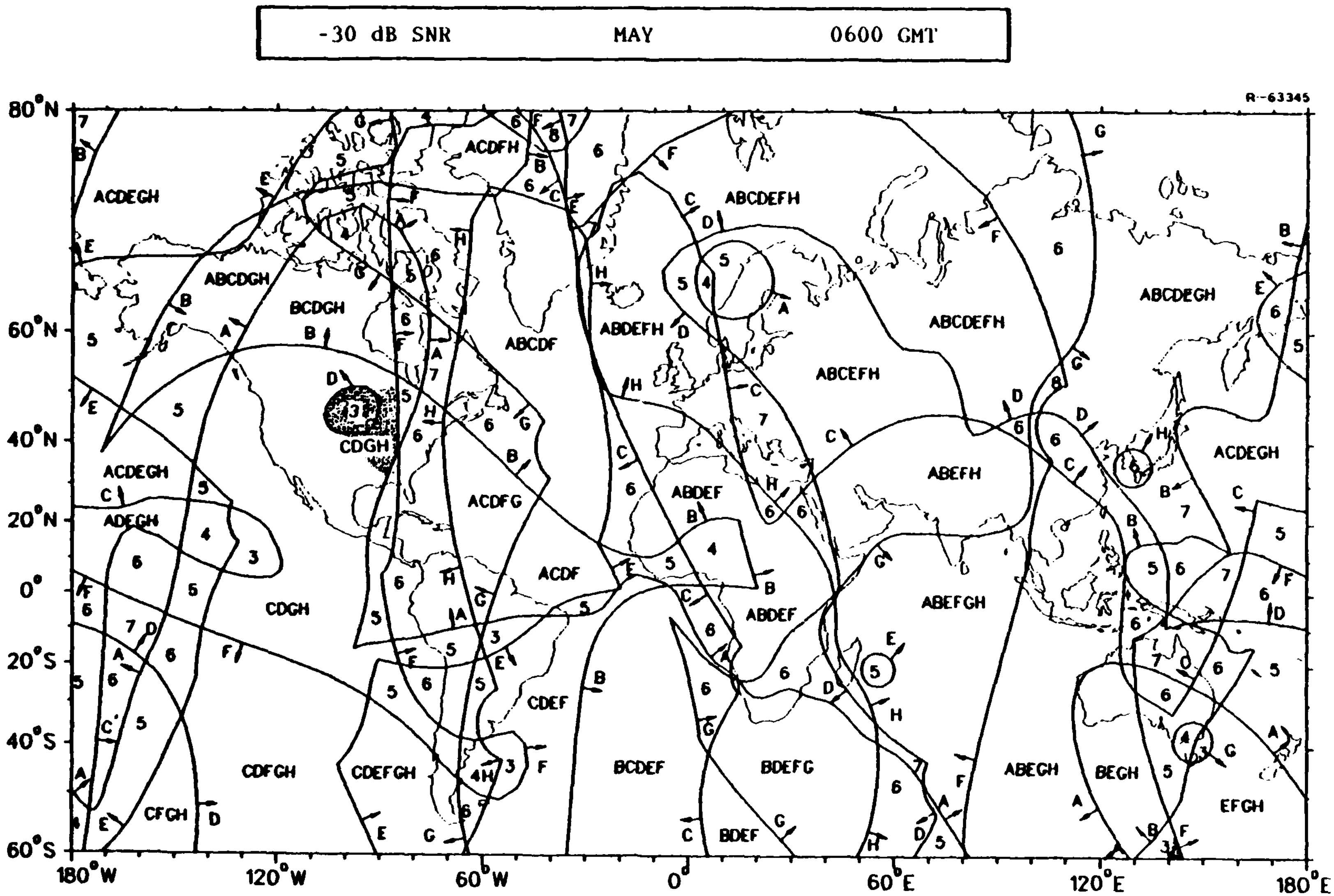


Figure A-6. OMEGA Composite Coverage Diagram (-30db, May, 0600 GMT)

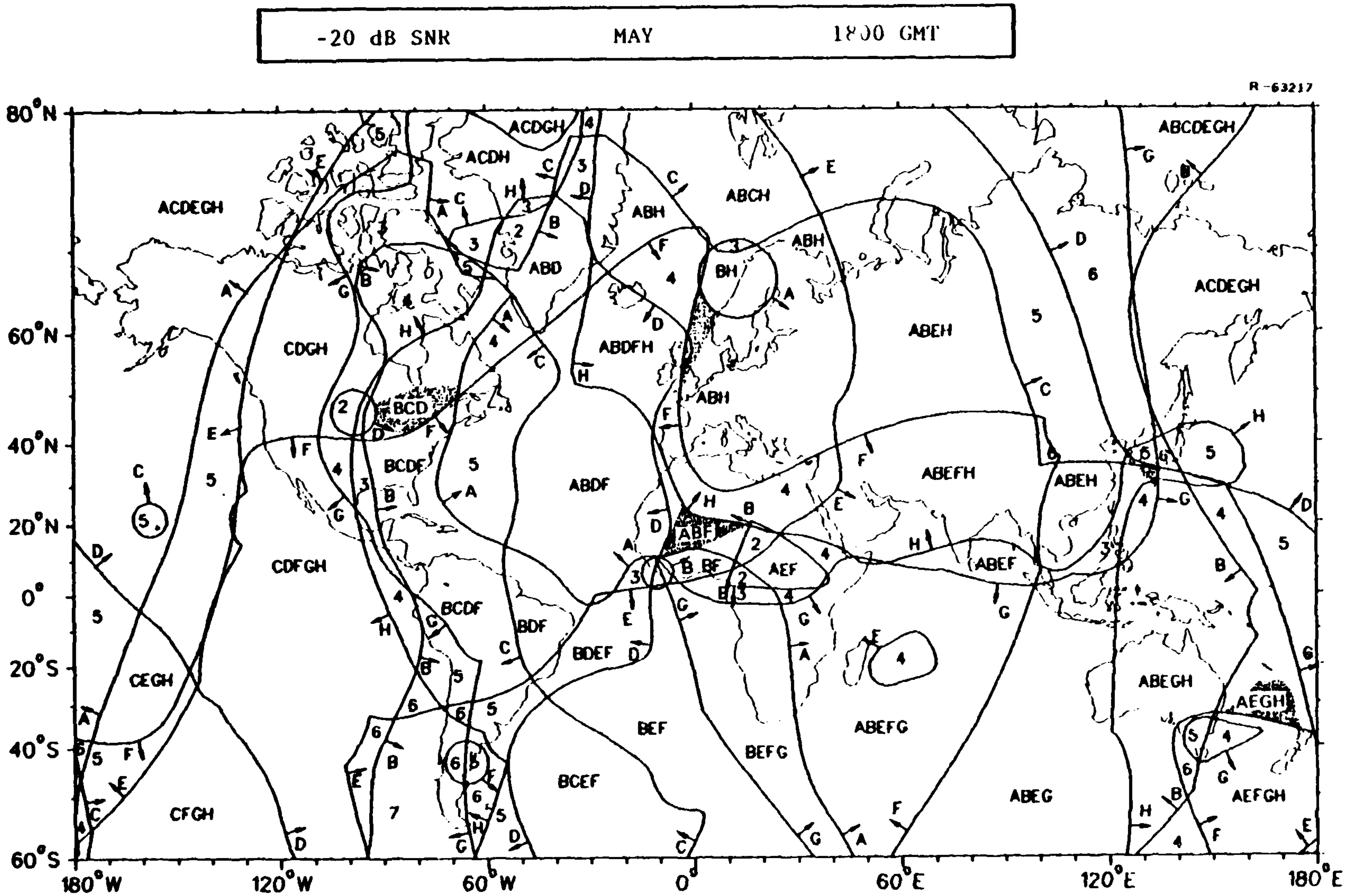


Figure A-7. OMEGA Composite Coverage Diagram (-20db, May, 1800 GMT)

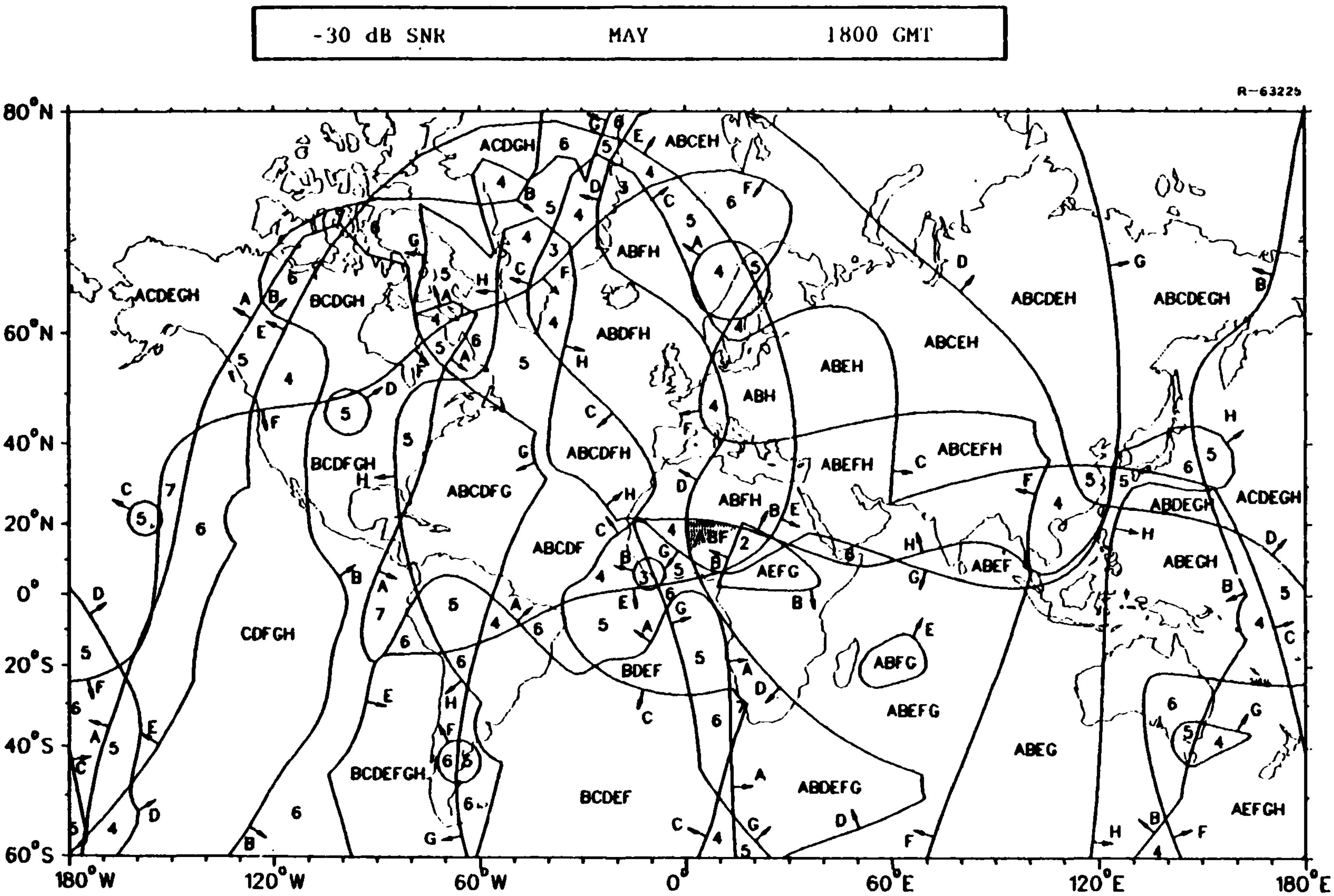


Figure A-8. OMEGA Composite Coverage Diagram (-30db, May, 1800 GMT)

-20 dB SNR AUGUST 0600 GMT

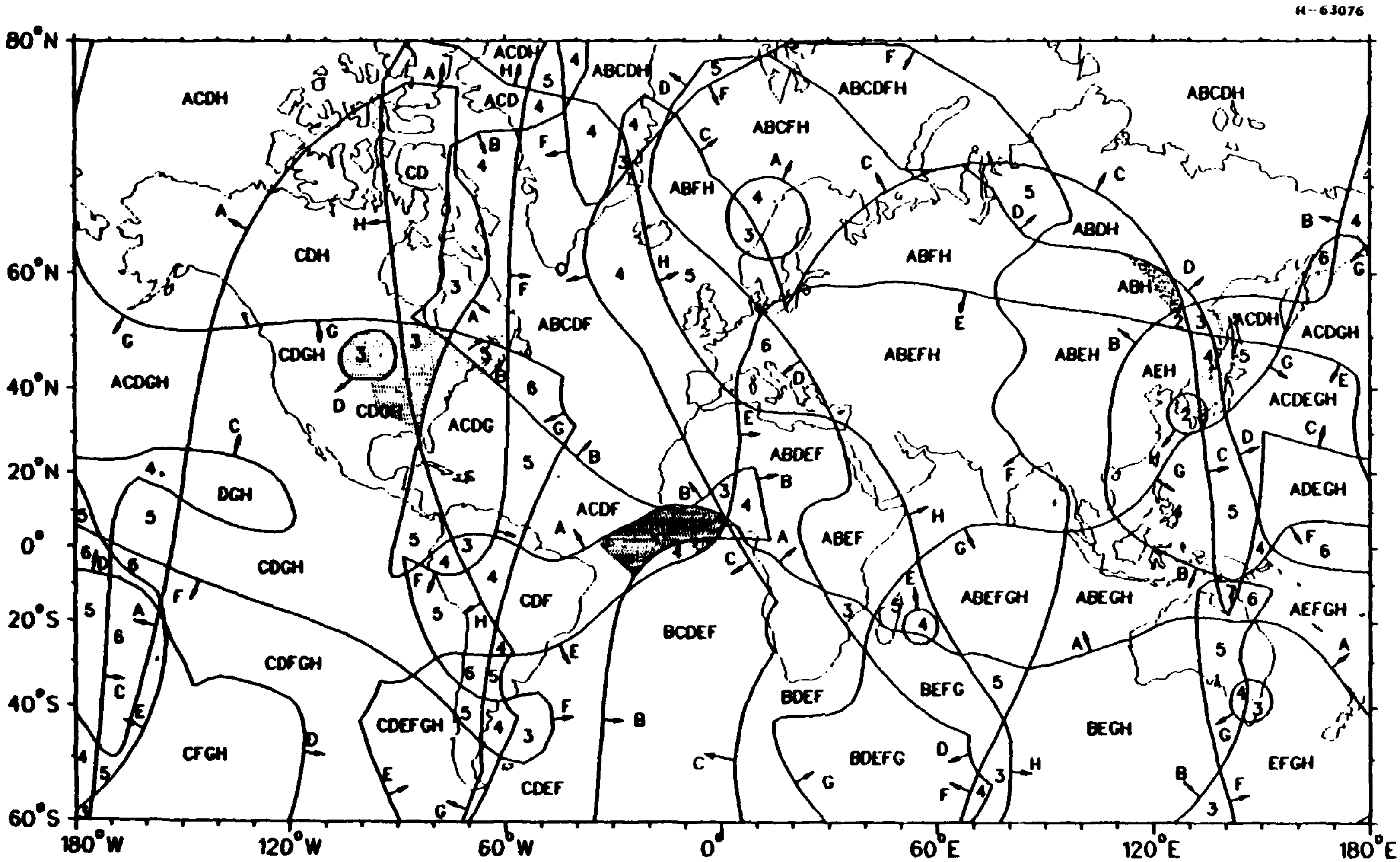


Figure A-9. OMEGA Composite Coverage Diagram (-20db, Aug., 0600 GMT)

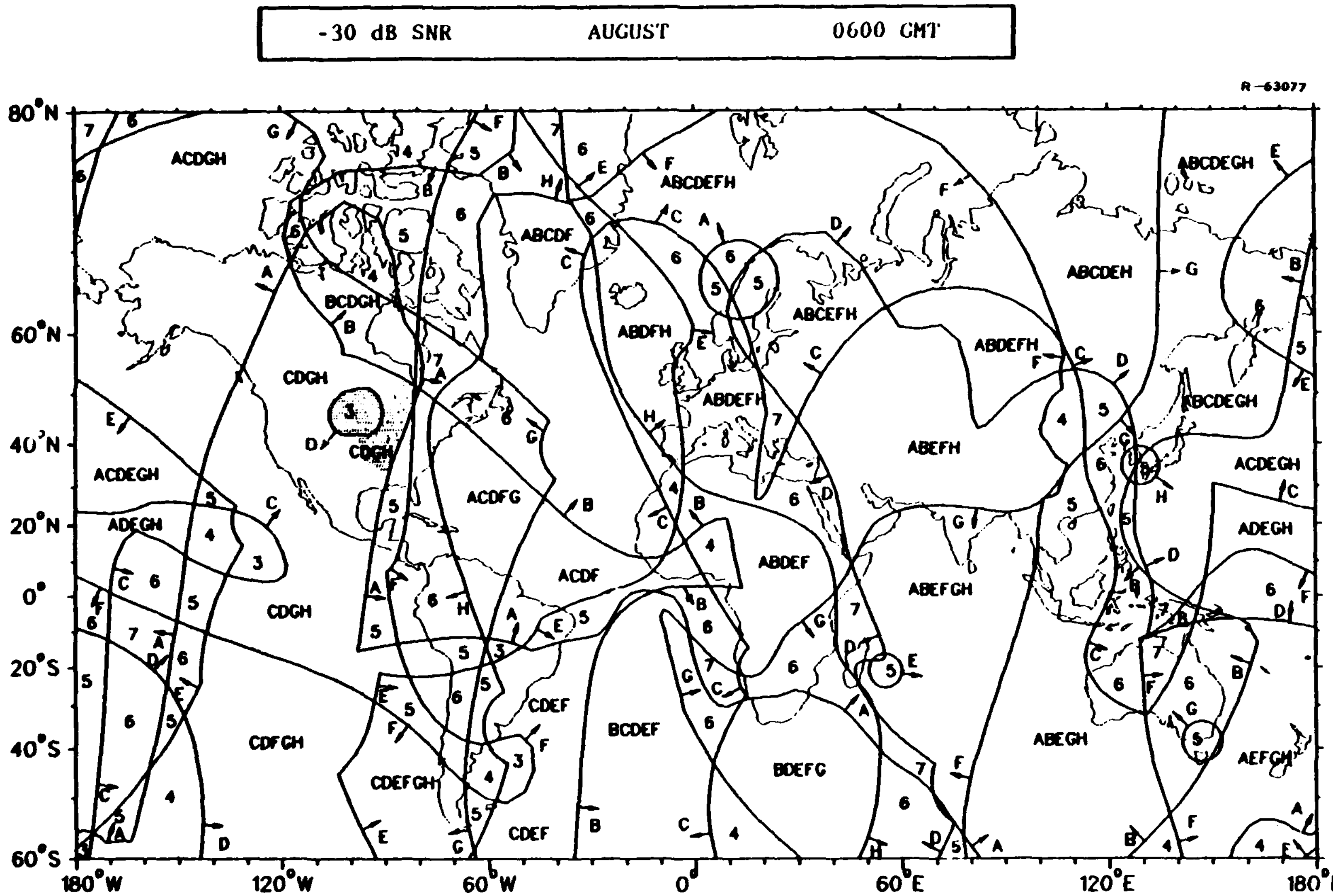


Figure A-10. OMEGA Composite Coverage Diagram (-30db, Aug., 0600 GMT)

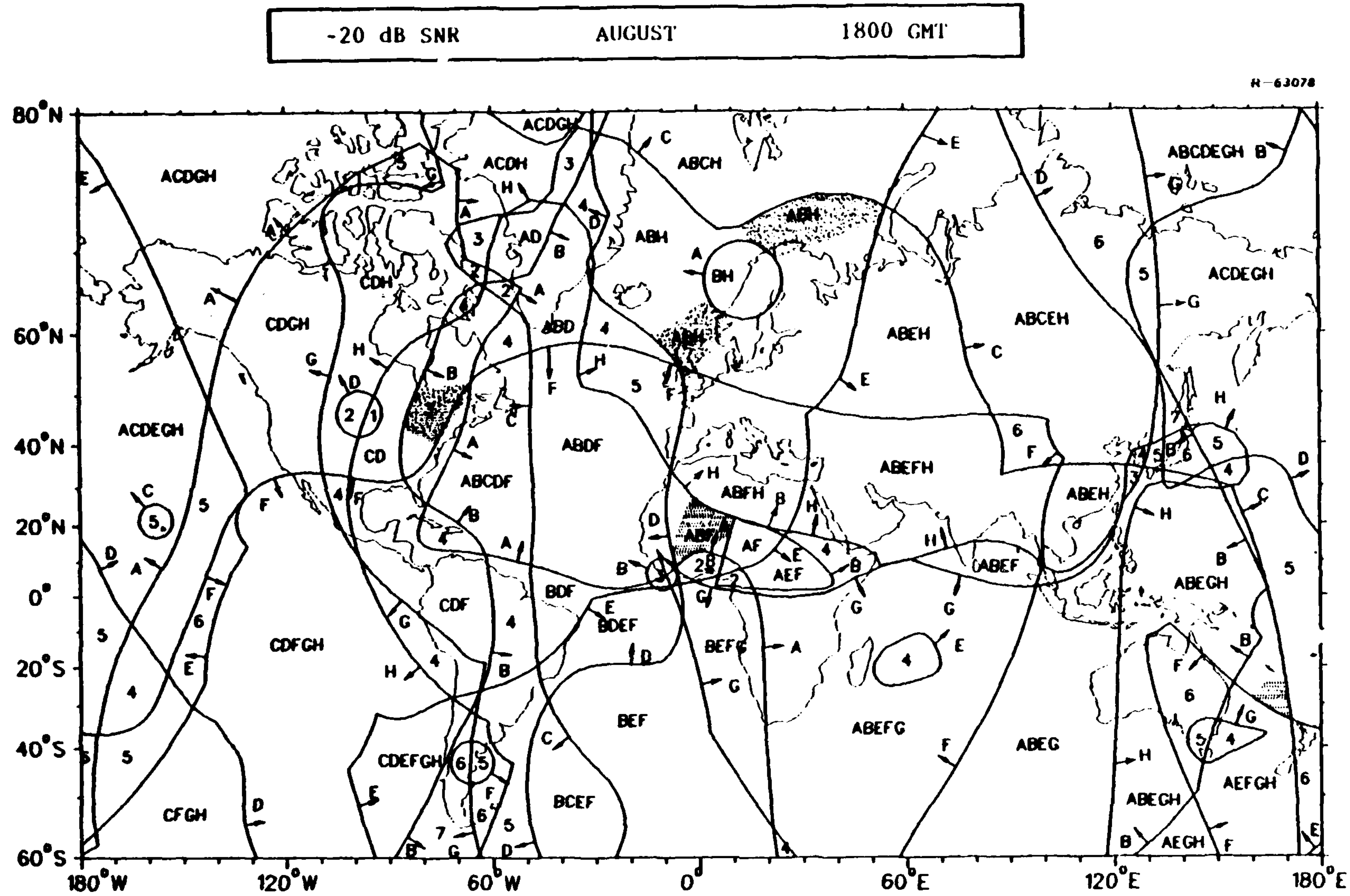


Figure A-11. OMEGA Composite Coverage Diagram (-20db, Aug., 1800 GMT)

-30 dB SNR AUGUST 1800 GMT

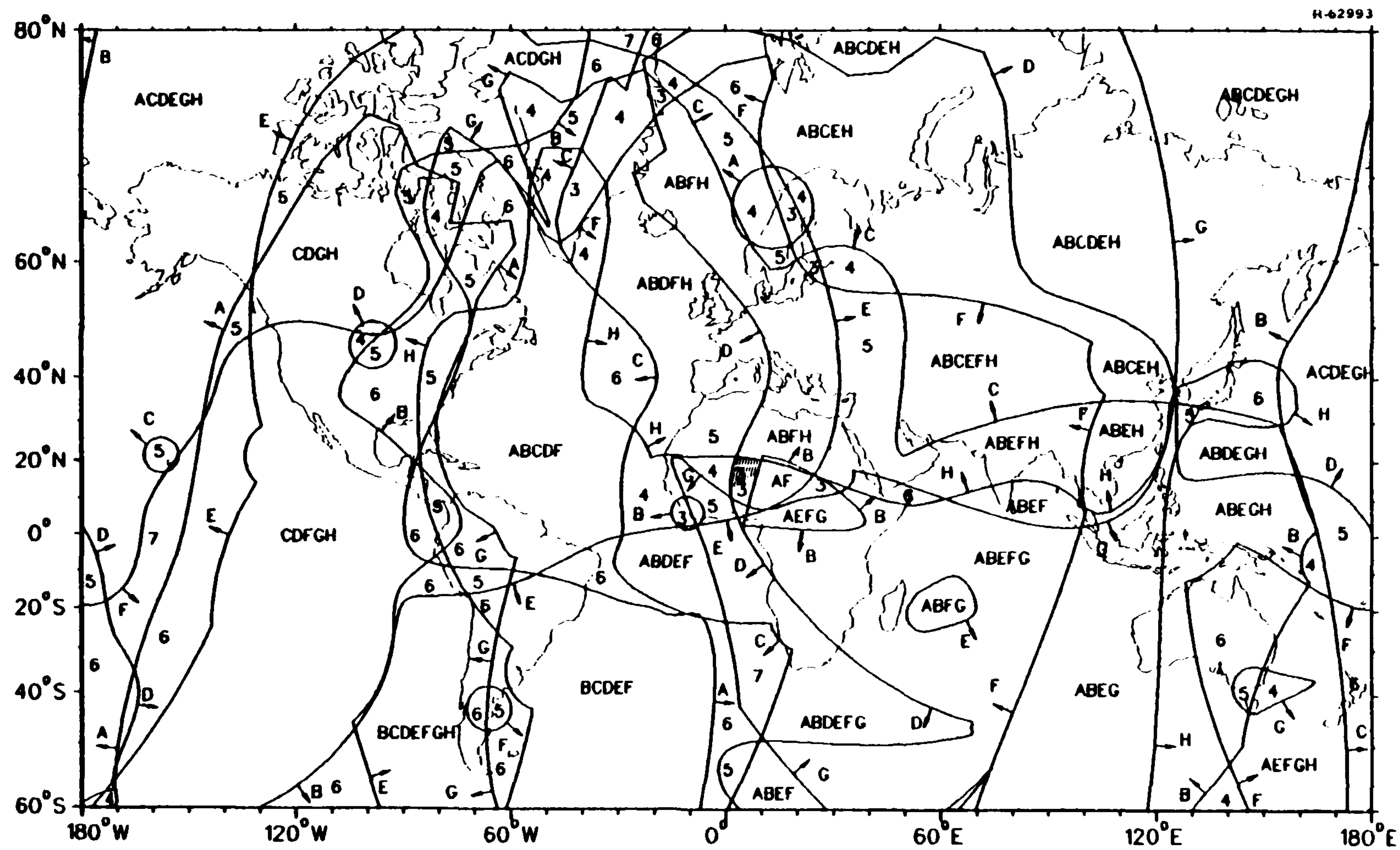


Figure A-12. OMEGA Composite Coverage Diagram (-30db, Aug., 1800 GMT)

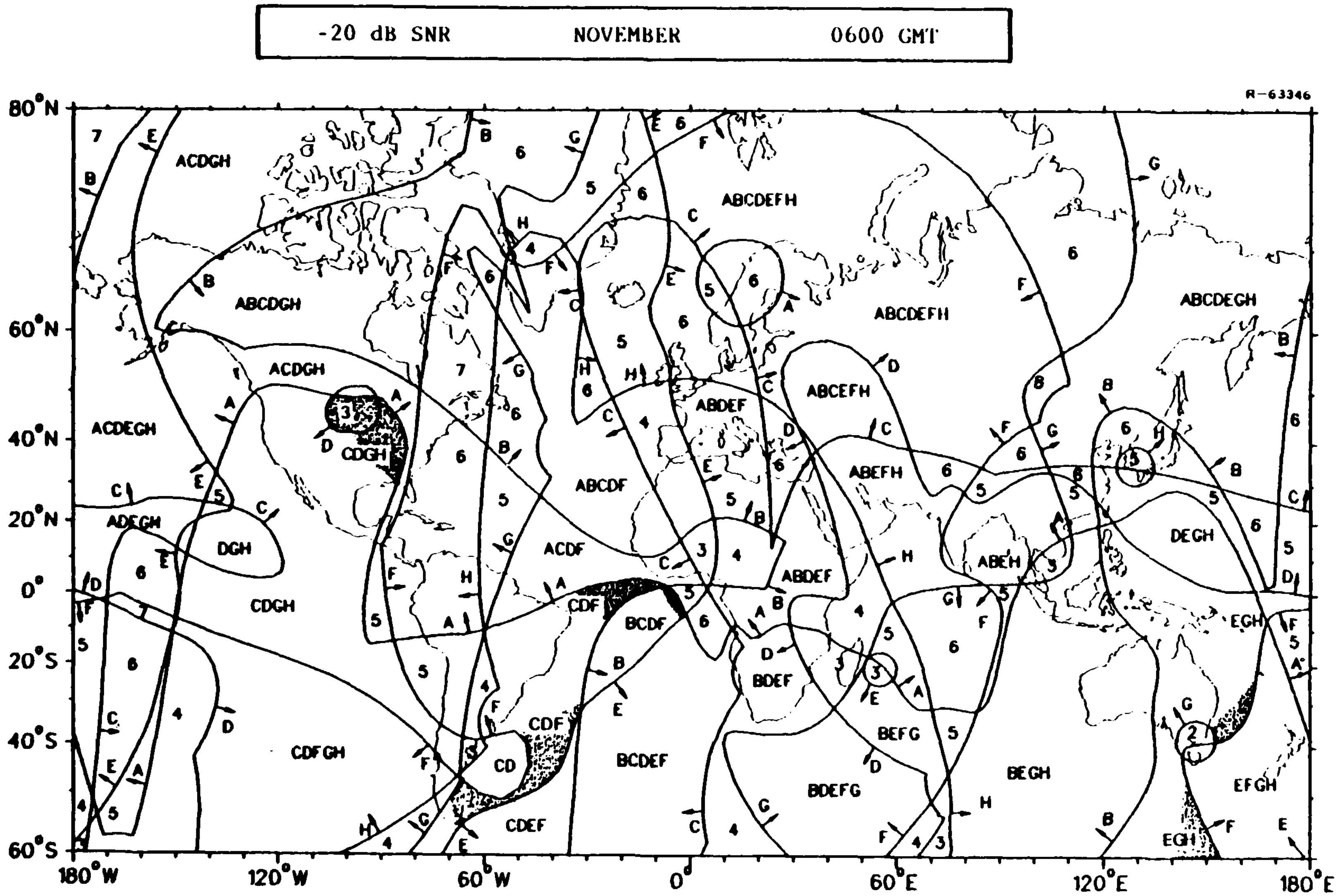


Figure A-13. OMEGA Composite Coverage Diagram (-20db, Nov., 0600 GMT)

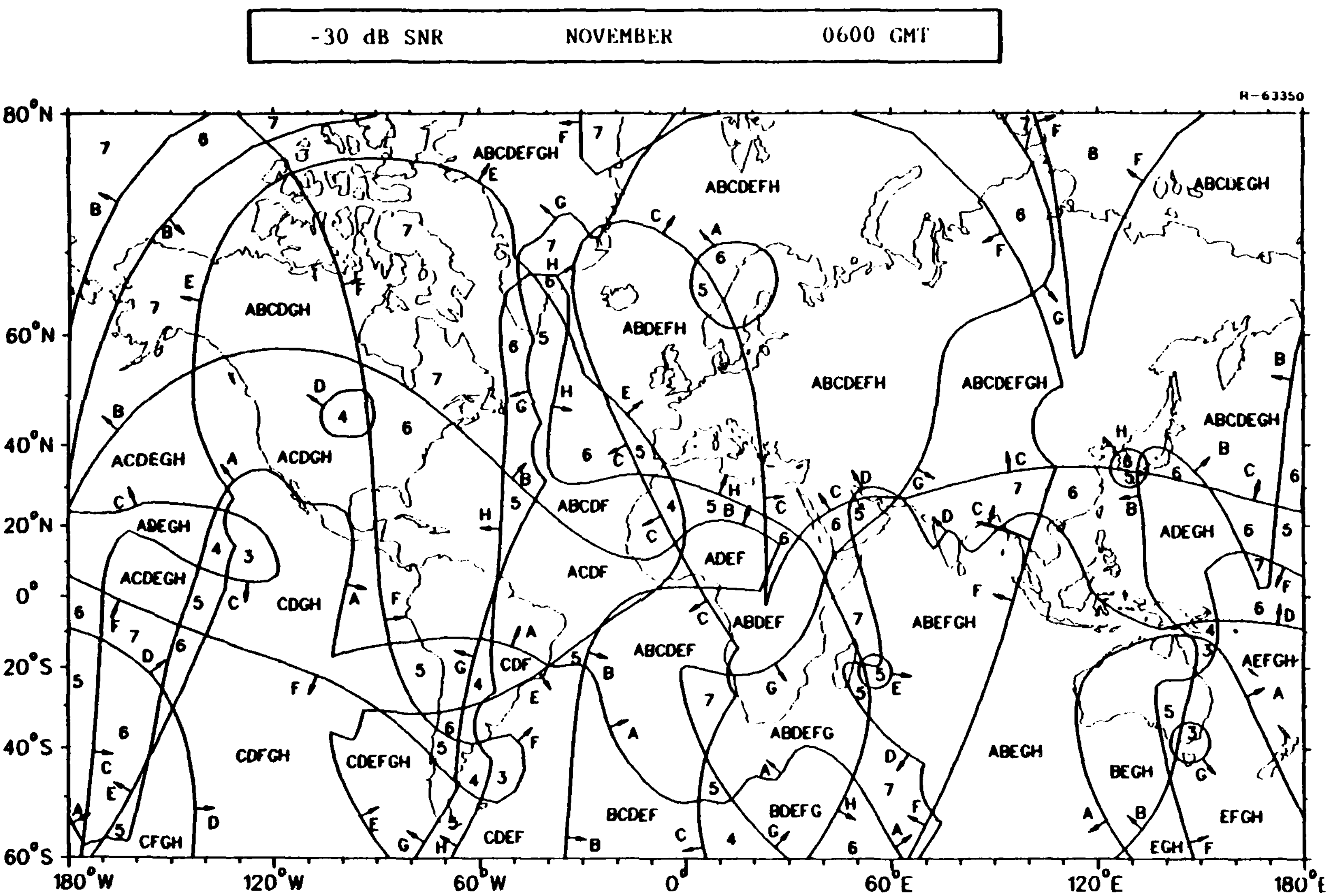


Figure A-14. OMEGA Composite Coverage Diagram (-30db, Nov., 0600 GMT)

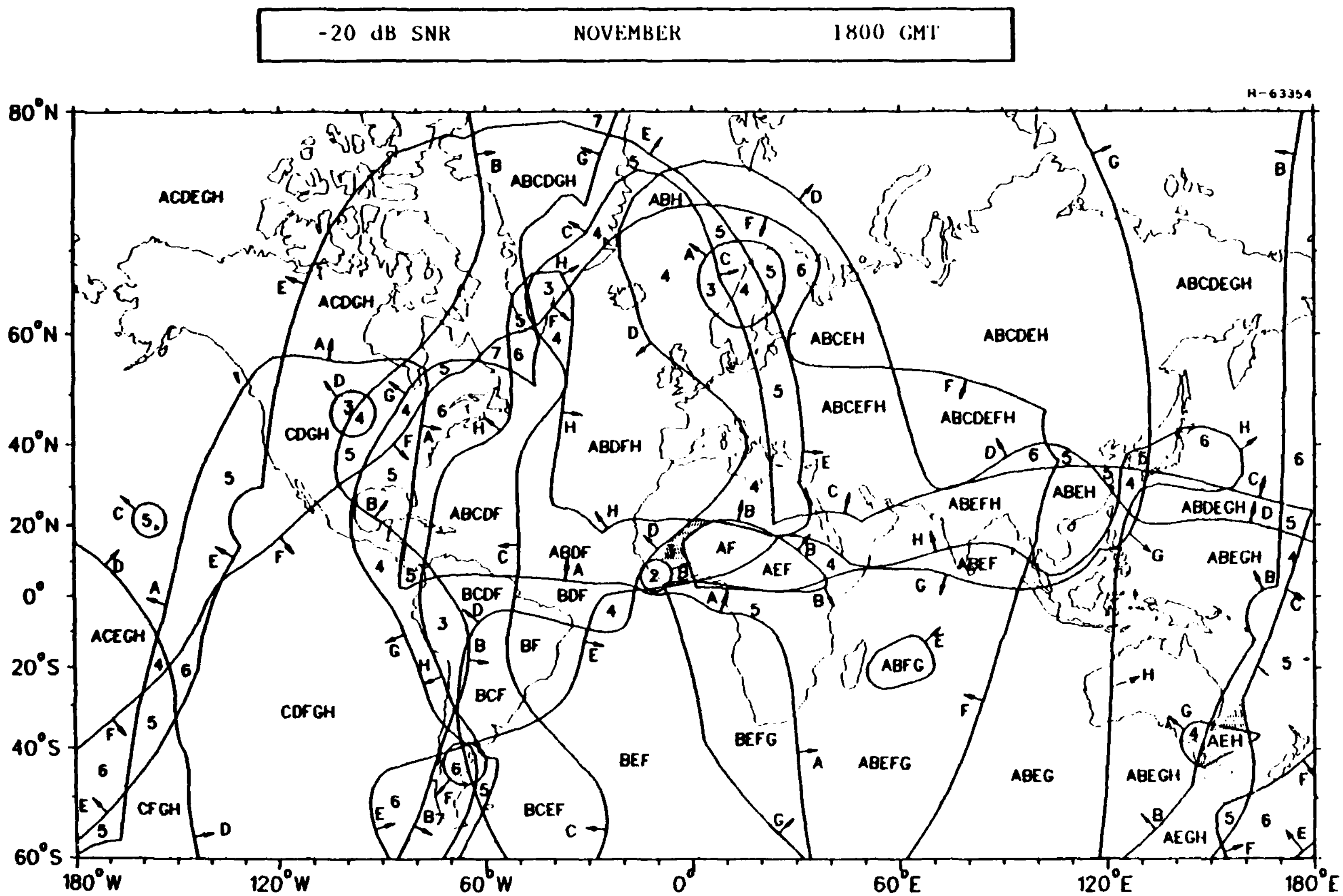


Figure A-15. OMEGA Composite Coverage Diagram (-20db, Nov., 1800 GMT)

-30 dB SNR NOVEMBER 1800 GMT

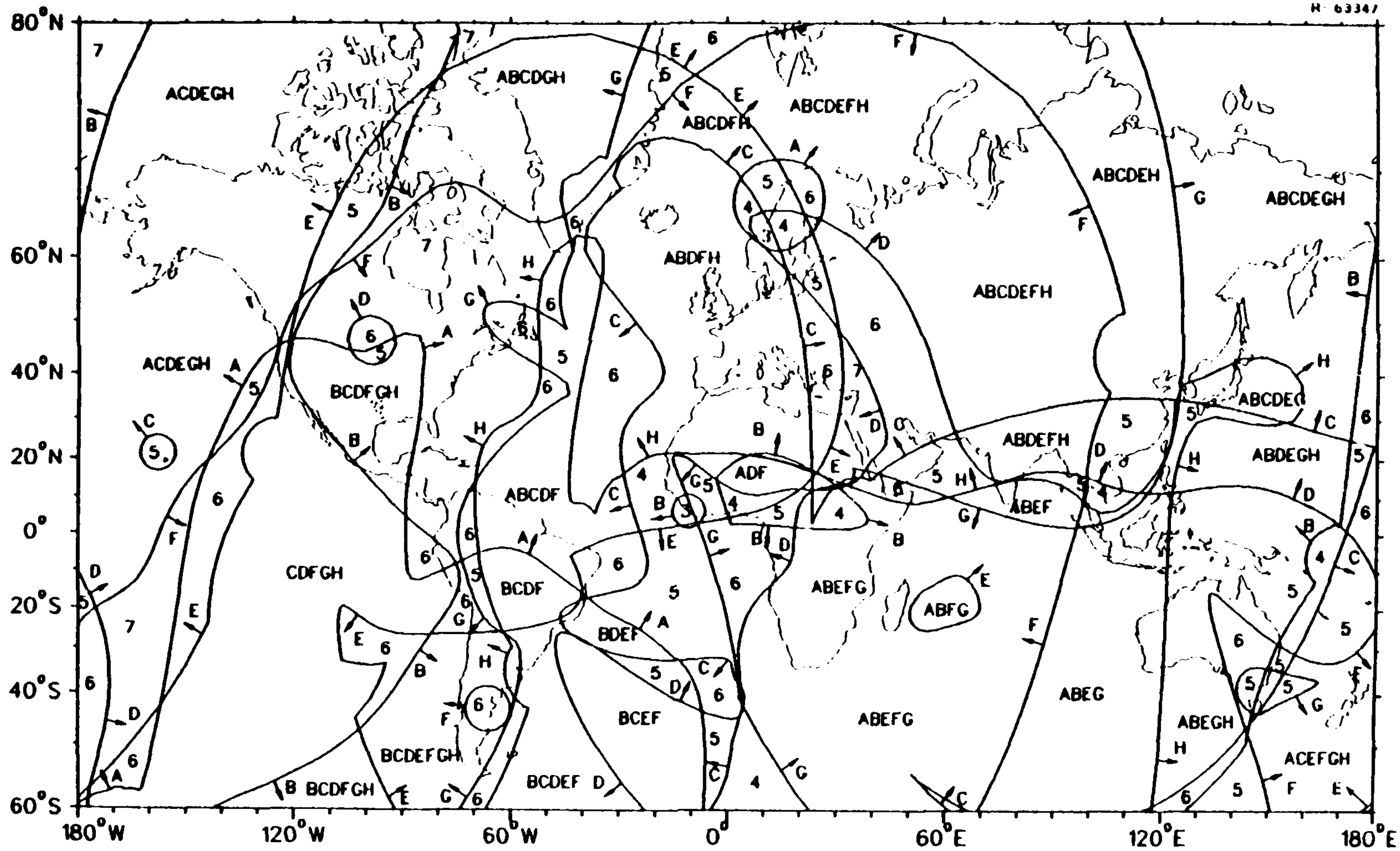


Figure A-16. OMEGA Composite Coverage Diagram (-30db, Nov., 1800 GMT)

APPENDIX B: MANUAL OMEGA FIX

One LOP defined by a single pair of transmitting stations will not identify a receiver location since the measured phase relationship will be the same everywhere along the LOP. A third station, paired with each of the first two, will yield a second and a third LOP. At least two LOPs are needed to define a position fix. For example, stations A and B yield station pair AB only. By adding station C, this yields station pairs AB, BC, and AC.

Useful signals from three stations can provide three intersecting LOPs, thereby enhancing confidence in the fix. Normally, two or more pairs of stations are used. The OMEGA system is designed to provide a fix accuracy of 4 nm or better, with a 95% confidence level. The system's accuracy is directly dependent upon the stability and predictablity of phase variations along the signal propagation paths. Based on the OMEGA transmission format, completely new position fix information is available once every 10 seconds.

Figure B-1 shows the operational procedures used in determining and plotting the position of a vessel transiting the Pacific Ocean. This example will be referred to throughout this section. The procedures in this section pertain to the use of an LOP OMEGA receiver only. A LAT/LONG OMEGA receiver allows plotting of the geographic coordinates directly on the chart.

Prior to departure from port, the navigator must select pairs of OMEGA transmitting stations to be used. In the example (Figure B-1) stations C (Hawaii), D (North Dakota), and H (Japan) were selected and paired as follows: C-D, C-H, D-H. While in port, the navigator plots his dockside position on the OMEGA chart and presets his receiver by entering the selected pairs of stations. Once set, the receiver should keep an accurate, continuous track of the OMEGA LOP numbers throughout the voyage. Additional station pairs may have to be selected on long voyages. Following departure from port, the navigator reads the lane values from the display on his receiver, applies the PPC to the receiver readings, and plots the numbered LOPs on his OMEGA chart. The following paragraphs describe the step-by-step procedures used by the navigator in plotting an enroute position fix using the OMEGA Navigation Worksheet (see Figure B-2). This procedure is for LOP receivers only, using 10.2 kHz.

Step 1 - Enter the date and time on the worksheet. Be sure to enter GMT and GMT date. (Entry of the local date and local time is optional.)

Step 2 - Enter the most accurate latitude and longitude obtainable.

Step 3 - Enter selected OMEGA LOPs in the LOP column (C-D, C-H, D-H). Be sure that any one station is not common to all LOPs.

Step 4 - Enter OMEGA readings for lane values from the receiver (See Figure B-1). Note that the lane values are read to at least a hundredth of a lane.

Step 5 - Determine the OMEGA area from Figure B-3. (This figure appears as Figure 1 in each OMEGA Table book.) For example, the DR latitude and longitude in Figure B-1 places the ship in Area 10.

Step 6 Look up the OMEGA PPC's for stations C, D, and H. For example, to obtain the correction for station C, use the OMEGA PPC table for 10.2 kHz for Area 10, station C (Hawaii). The OMEGA PPC table page index is in Figure B-4.

Step 7 - Figure B-4 appears as Page 1 in the OMEGA PPC table. Locate the page corresponding to the ship's present position using the DR latitude and longitude from the worksheet. The DR latitude and longitude places the ship in a block numbered 85, centered at 40 degrees N, 144 degrees W. This means that the PPC for all three stations will be found on page 85 of the PPC table.

Step 8 - From Figure B-5(a), determine the PPC for station C based upon GMT date and GMT time (19 Dec, 1200) recorded on your worksheet. The correction for C is 0.36. Note that corrections are in units termed CECs, which for all practical purposes are the same as CELs. The decimal is therefore placed before the correction value to make it compatible with fractional lane readings.

Step 9 - Locate PPC's for each of the other two stations (D and H) in Figures B-5(b) and B-5(c). The values are (D = - 0.49, H = - 0.78).

Step 10 - Record each PPC on the OMEGA navigation worksheet (Figure B-2).

Step 11 - Convert these station corrections (PPCs) to station pair corrections as follows:

(PPC Sta. 1) - (PPC sta. 2) = Sta. Pair 1 & 2 Correction

For Station Pair C & D
(C) - (D)

$(-0.36) - (-0.49) = C - D$ Correction
$(-0.36) + (0.49) = C - D$ Correction
$+0.13 = C - D$ Correction

Algebraic subtraction is always used. A good rule to remember is to reverse the sign of the second PPC and add it to the first PPC.

The LOP correction for C & H and D & H can be determined in a similar manner:

C - H LOP Correction = +0.42
D - H LOP Correction = +0.29

Note that the decimal has been placed before all corrections so that they can be applied to the receiver reading.

Step 12 - Record each of the corrections in the "Correction" column on the worksheet (Figure B-2).

Step 13 - Apply the corrections to the OMEGA receiver readings and record the corrected readings in the right hand column of the OMEGA worksheet (Figure B-2).

Step 14 - Plot these corrected LOPs on the OMEGA chart to obtain the position fix. Figure B-6 illustrates how the corrected LOPs would be plotted on the OMEGA chart used for this example. LOP D-H has been omitted for simplification of the diagram.

The lanes printed on the chart are in three lane intervals, e.g., CH731, 734, 737 CD859, 862, 865. The LOP's that are plotted on the chart in this example are CH = 732.54 and CD = 860.85. Thus, the 731 and 734 CD lanes and the 859 and 862 lanes must be interpolated.

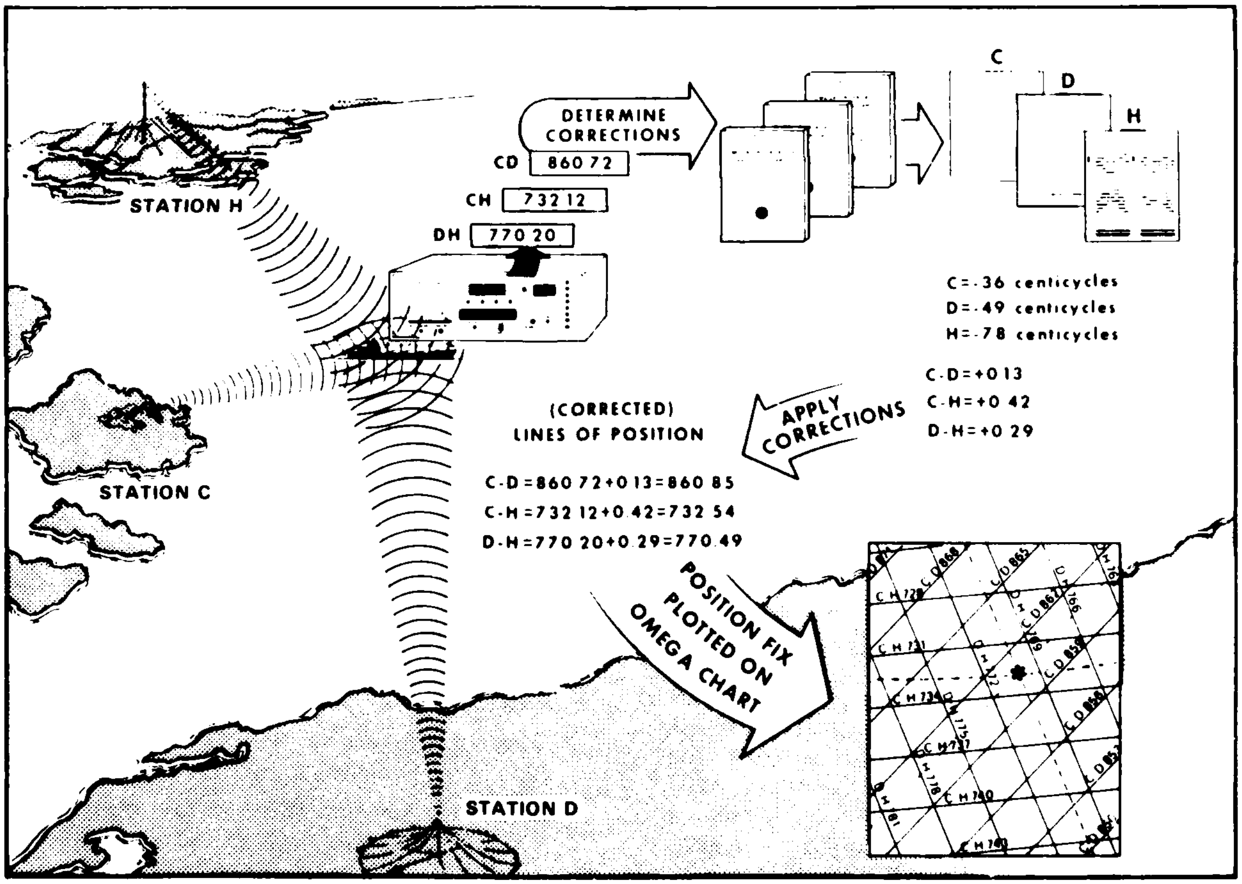


Figure B-1. Procedure for Manually Plotting a Position

STEP 1

STEP 2

DATE 19 Dec. 1975

DR LATITUDE 40°-3'N

DR LONGITUDE 144°-30'W

LOCAL TIME 0400

GMT 1200

GMT DATE 19 DEC 1975

STEP 3 STEP 4 STEP 12 STEP 13

LOP

STEP 10

STATION	PPC	LOP DESIGNATION		READING	CORRECTION	CORRECTED READING
A		1	C-D	860.72	+0.13	860.85
B		2	C-H	732.12	+0.42	732.54
C	-36	3	D-H	770.20	+0.29	770.49
D	-49	4				
E						
F						
G						
H	-78					

Figure B-2. OMEGA Navigation Worksheet

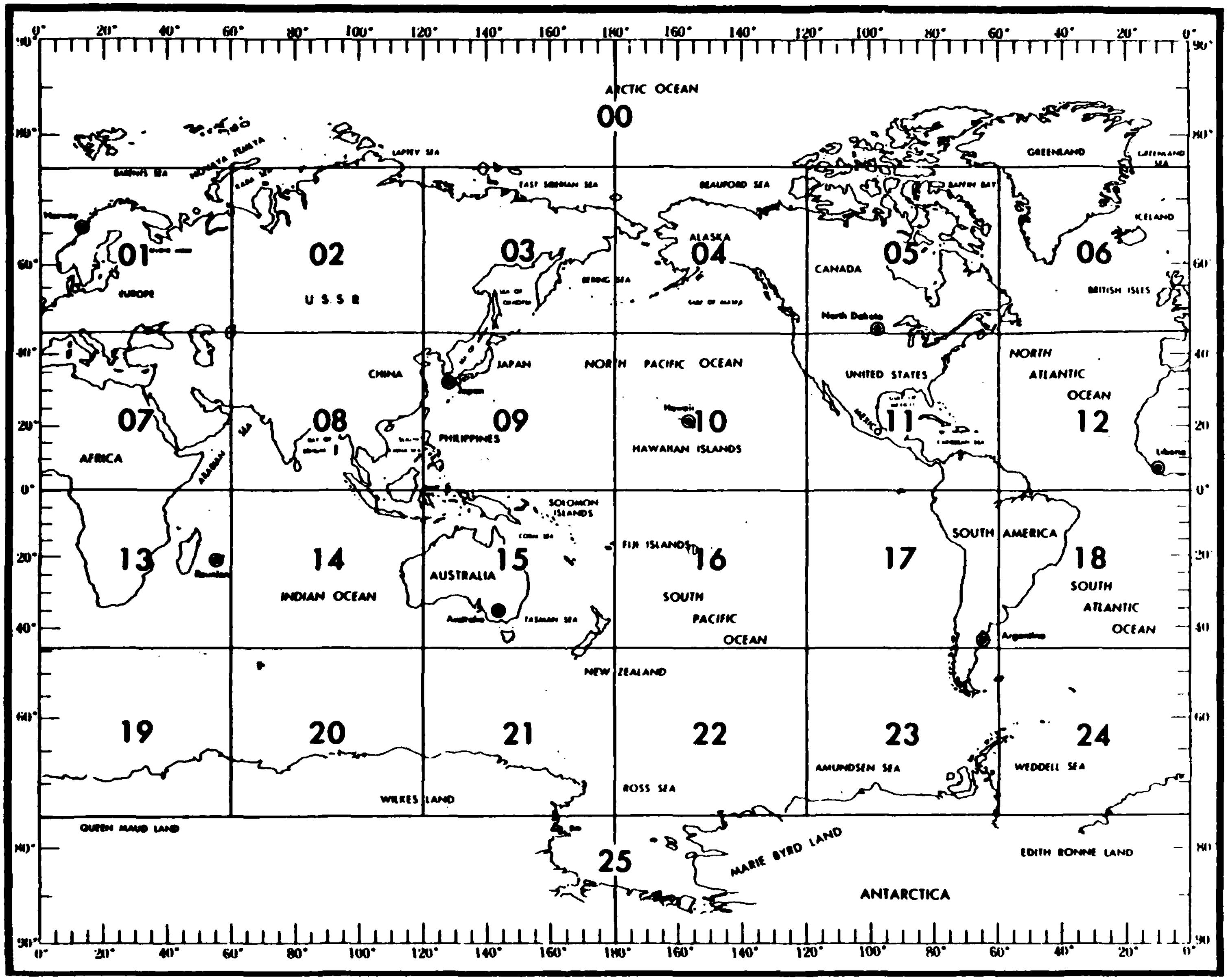
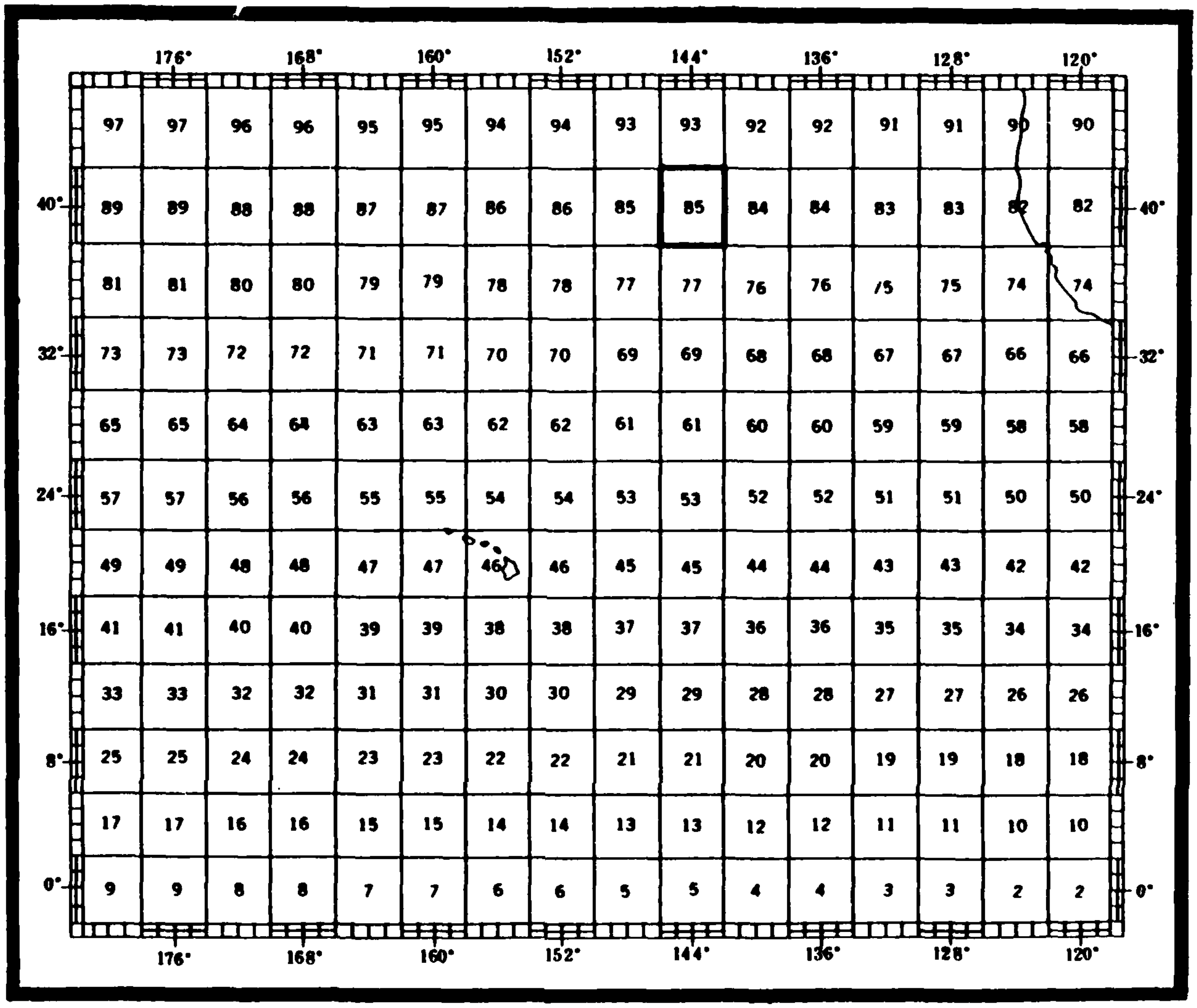


Figure B-3. OMEGA Table Areas



Corrections for a particular quadrangle can be located in this table by referring to the page numbers in the above index.

Figure B-4. Page Index to Propagation Corrections

10.2 KHZ OMEGA PROPAGATION CORRECTIONS IN UNITS OF CECS

LOCATION 40.0 N 144.0 W
STATION C HAWAII

DATE	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1-15 JAN	-9	-10	-14	-22	-32	-35	-37	-37	-37	-37	-37	-36	-37	-38	-38	-39	-38	-8	-7	-12	-10	-10	-9	-8	-9
16-31 JAN	-8	-9	-12	-20	-30	-35	-36	-37	-37	-37	-37	-36	-37	-38	-38	-39	-38	-7	-7	-12	-9	-9	-9	-8	-8
1-14 FEB	-7	-9	-10	-16	-28	-34	-36	-37	-37	-37	-37	-37	-37	-38	-38	-39	-38	-5	-9	-11	-9	-8	-7	-7	-7
15-29 FEB	-7	-8	-9	-14	-25	-34	-35	-36	-37	-37	-37	-37	-37	-37	-38	-39	-32	-4	-10	-10	-8	-7	-7	-7	-7
1-15 MAR	-7	-8	-9	-13	-23	-33	-35	-36	-37	-37	-37	-37	-37	-37	-38	-39	-23	-4	-10	-9	-8	-7	-6	-6	-7
16-31 MAR	-7	-8	-9	-11	-21	-32	-35	-36	-37	-37	-37	-36	-37	-37	-38	-38	-13	-6	-11	-9	-7	-6	-6	-6	-7
1-15 APR	-8	-6	-8	-10	-20	-24	-34	-36	-37	-37	-37	-37	-36	-40	-39	-34	-8	-9	-11	-9	-8	-7	-7	-7	-8
16-30 APR	-9	-8	-9	-10	-18	-27	-33	-36	-37	-37	-37	-36	-38	-36	-38	-25	-9	-11	-10	-9	-7	-6	-6	-6	-9
1-15 MAY	-5	-6	-8	-10	-16	-27	-32	-34	-36	-37	-35	-36	-36	-36	-35	-20	-10	-13	-11	-8	-6	-6	-6	-5	-5
16-31 MAY	-5	-6	-8	-8	-13	-25	-31	-34	-36	-37	-35	-36	-36	-36	-32	-16	-11	-14	-11	-8	-7	-6	-6	-4	-5
1-15 JUN	-7	-8	-9	-10	-13	-23	-32	-35	-36	-37	-37	-37	-37	-36	-30	-15	-10	-14	-11	-9	-7	-7	-7	-6	-7
16-30 JUN	-6	-7	-9	-10	-13	-22	-31	-36	-37	-37	-37	-37	-37	-37	-30	-17	-10	-12	-10	-8	-7	-5	-5	-5	-6
1-15 JUL	-7	0	-14	-13	-14	-23	-32	-36	-37	-37	-37	-37	-37	-36	-31	-17	-13	-12	-8	-12	-19	-6	-8	-7	-7
16-31 JUL	-7	-4	-11	-12	-15	-24	-32	-36	-36	-37	-37	-38	-36	-35	-32	-21	-16	-12	-10	-10	-6	-4	-7	-4	-7
1-15 AUG	-6	-8	-11	-12	-16	-27	-33	-35	-36	-37	-37	-37	-36	-35	-34	-24	-13	-16	-13	-10	-7	-7	-5	-5	-6
16-31 AUG	-5	-8	-11	-12	-19	-30	-33	-36	-37	-37	-37	-37	-36	-35	-34	-29	-12	-14	-12	-9	-8	-6	-5	-4	-5
1-15 SEP	-6	-11	-11	-17	-25	-35	-37	-40	-41	-41	-36	-39	-34	-36	-37	-34	-14	-14	-12	-9	-7	-3	-6	-6	-6
16-30 SEP	-9	-13	-12	-18	-28	-34	-36	-38	-40	-41	-37	-39	-34	-36	-41	-40	-14	-12	-12	-10	-8	-7	-7	-7	-9
1-15 OCT	-9	-10	-13	-19	-30	-34	-37	-38	-37	-37	-36	-35	-35	-37	-41	-44	-17	-11	-13	-10	-9	-8	-7	-8	-9
16-31 OCT	-10	-11	-14	-21	-31	-35	-37	-37	-37	-37	-35	-34	-35	-38	-42	-44	-19	-8	-13	-10	-9	-8	-8	-8	-10
1-15 NOV	-10	-12	-17	-25	-33	-35	-38	-37	-37	-37	-35	-35	-37	-40	-42	-43	-27	-6	-12	-11	-9	-9	-9	-10	-10
16-30 NOV	-9	-11	-18	-25	-34	-36	-39	-37	-39	-39	-34	-37	-39	-42	-40	-41	-35	-7	-13	-12	-11	-9	-9	-9	-9
1-15 DEC	-8	-10	-16	-25	-33	-37	-38	-37	-37	-37	-36	-36	-36	-39	-41	-41	-40	-4	-10	-12	-9	-9	-9	-8	-8
16-31 DEC	-8	-10	-15	-24	-33	-37	-38	-37	-37	-37	-36	-36	$\boxed{-36}$	-39	-40	-42	-40	-6	-9	-13	-10	-9	-9	-8	-8

LOCATION 40.0 N 148.0 W
STATION C HAWAII

DATE	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1-15 JAN	-9	-10	-13	-19	-29	-34	-35	-35	-35	-35	-35	-35	-35	-36	-36	-37	-36	-12	-7	-12	-10	-10	-9	-8	-9
16-31 JAN	-9	-9	-11	-17	-27	-33	-34	-35	-35	-35	-35	-35	-35	-36	-36	-37	-36	-11	-7	-12	-10	-10	-8	-8	-9
1-14 FEB	-8	-9	-10	-15	-25	-32	-34	-34	-35	-35	-35	-35	-35	-36	-36	-37	-36	-7	-9	-11	-9	-8	-8	-8	-8
15-29 FEB	-8	-8	-9	-13	-22	-32	-33	-34	-35	-35	-35	-35	-35	-35	-36	-37	-35	-6	-10	-10	-9	-8	-7	-7	-8
1-15 MAR	-7	-8	-9	-12	-21	-30	-33	-34	-35	-35	-35	-35	-35	-35	-36	-36	-28	-5	-10	-10	-8	-7	-7	-7	-7
16-31 MAR	-7	-8	-9	-11	-19	-29	-33	-34	-35	-35	-35	-34	-35	-35	-36	-36	-16	-6	-11	-9	-8	-7	-7	-7	-7
1-15 APR	-9	-6	-9	-10	-18	-23	-32	-34	-35	-35	-35	-35	-34	-38	-37	-35	-10	-9	-11	-10	-8	-8	-7	-7	-9
16-30 APR	-9	-8	-8	-10	-17	-25	-31	-34	-34	-35	-35	-34	-36	-34	-35	-28	-11	-12	-11	-9	-8	-6	-7	-7	-9
1-15 MAY	-5	-6	-8	-10	-14	-24	-30	-32	-34	-35	-33	-34	-34	-34	-34	-22	-10	-13	-10	-9	-7	-7	-7	-6	-5
16-31 MAY	-5	-6	-8	-9	-12	-22	-29	-32	-34	-35	-34	-34	-34	-34	-33	-17	-10	-13	-11	-9	-8	-7	-7	-5	-5
1-15 JUN	-7	-8	-9	-10	-12	-21	-30	-33	-34	-35	-35	-35	-35	-34	-31	-15	-11	-13	-11	-10	-8	-7	-7	-7	-7
16-30 JUN	-6	-8	-9	-10	-11	-20	-30	-33	-34	-35	-35	-35	-35	-35	-31	-16	-11	-12	-10	-9	-7	-6	-6	-6	-6
1-15 JUL	-7	-2	-13	-13	-13	-21	-31	-34	-35	-35	-35	-35	-35	-34	-31	-19	-14	-11	-8	-12	-19	-7	-9	-8	-7
16-31 JUL	-7	-5	-11	-11	-14	-21	-30	-34	-34	-35	-35	-36	-34	-34	-33	-22	-16	-12	-10	-10	-7	-5	-8	-5	-7
1-15 AUG	-6	-8	-11	-12	-15	-24	-31	-33	-34	-35	-35	-35	-34	-33	-32	-26	-13	-16	-13	-9	-8	-7	-6	-6	-6
16-31 AUG	-5	-8	-10	-12	-17	-27	-31	-33	-34	-35	-35	-35	-34	-33	-32	-30	-13	-14	-12	-9	-8	-6	-6	-5	-5
1-15 SEP	-7	-12	-11	-15	-22	-32	-35	-37	-38	-38	-34	-37	-32	-34	-35	-37	-14	-15	-12	-9	-7	-5	-6	-6	-7
16-30 SEP	-9	-12	-12	-16	-24	-32	-34	-36	-38	-38	-35	-37	-33	-35	-38	-39	-16	-13	-13	-11	-9	-8	-8	-8	-9
1-15 OCT	-10	-10	-13	-17	-27	-32	-34	-35	-35	-35	-34	-33	-33	-35	-39	-42	-18	-11	-13	-10	-9	-8	-8	-8	-10
16-31 OCT	-10	-11	-13	-19	-29	-33	-35	-35	-35	-35	-33	-32	-33	-36	-39	-42	-23	-9	-13	-11	-8	-9	-8	-9	-10
1-15 NOV	-11	-12	-15	-23	-31	-33	-35	-35	-35	-35	-33	-33	-35	-38	-40	-41	-32	-7	-11	-11	-10	-9	-10	-10	-11
16-30 NOV	-9	-11	-17	-21	-32	-34	-37	-35	-37	-37	-32	-35	-37	-39	-38	-39	-37	-8	-12	-13	-11	-9	-9	-9	-9
1-15 DEC	-8	-10	-14	-23	-31	-34	-35	-35	-35	-35	-34	-34	-34	-37	-38	-39	-37	-7	-9	-13	-10	-9	-9	-9	-8
16-31 DEC	-8	-10	-14	-21	-31	-34	-35	-35	-35	-35	-34	-34	-34	-37	-38	-39	-37	-9	-9	-12	-10	-9	-10	-9	-8

Figure B-5(a). Propagation Corrections Station C

OMEGA PROPAGATION CORRECTIONS FOR 10.2 KHZ

LOCATION 40.0 N 144.0 W
STATION D NORTH DAKOTA

DATE	00	01	02	03	04	05	06	07	08	09	10	GMT 11	12	13	14	15	16	17	18	19	20	21	22	23	24
1-15 JAN	-26	-35	-42	-46	-47	-48	-48	-48	-49	-49	-49	-49	-49	-49	-47	-33	-17	-12	-13	-11	-10	-9	-12	-17	-26
16-31 JAN	-22	-32	-40	-46	-47	-48	-48	-48	-49	-49	-49	-49	-49	-49	-46	-31	-15	-12	-12	-10	-9	-9	-10	-14	-22
1-14 FEB	-17	-28	-38	-44	-47	-48	-48	-48	-49	-49	-49	-49	-49	-49	-43	-27	-12	-11	-11	-9	-8	-8	-9	-11	-17
15-29 FEB	-14	-23	-34	-42	-46	-48	-48	-48	-48	-49	-49	-49	-49	-48	-36	-21	-10	-11	-10	-8	-7	-7	-8	-9	-14
1-15 MAR	-12	-19	-31	-40	-46	-47	-48	-48	-48	-49	-49	-49	-49	-45	-30	-15	-10	-10	-8	-7	-7	-7	-7	-8	-12
16-31 MAR	-10	-16	-27	-38	-45	-47	-48	-48	-48	-49	-49	-49	-48	-39	-24	-10	-10	-9	-7	-6	-6	-6	-6	-7	-10
1-15 APR	-8	-13	-23	-34	-43	-46	-48	-48	-48	-48	-49	-49	-45	-30	-16	-10	-10	-8	-6	-5	-5	-5	-5	-7	-8
16-30 APR	-8	-11	-19	-31	-41	-45	-47	-48	-48	-48	-49	-48	-39	-25	-12	-10	-9	-7	-6	-5	-4	-4	-5	-6	-8
1-15 MAY	-7	-10	-16	-28	-38	-44	-47	-48	-48	-48	-49	-46	-33	-19	-10	-10	-8	-6	-5	-4	-4	-4	-4	-6	-7
16-31 MAY	-7	-9	-14	-25	-36	-43	-46	-48	-48	-48	-48	-42	-29	-16	-11	-10	-8	-6	-5	-4	-3	-3	-4	-5	-7
1-15 JUN	-6	-8	-13	-22	-34	-42	-46	-47	-48	-48	-48	-39	-28	-14	-11	-9	-8	-6	-4	-4	-3	-3	-4	-5	-6
16-30 JUN	-6	-8	-12	-20	-32	-41	-45	-47	-48	-48	-48	-39	-28	-14	-11	-9	-8	-6	-4	-4	-3	-3	-4	-5	-6
1-15 JUL	-6	-8	-12	-21	-33	-41	-45	-47	-48	-48	-48	-42	-29	-16	-11	-10	-8	-6	-5	-4	-3	-3	-4	-5	-6
16-31 JUL	-6	-8	-13	-22	-34	-42	-46	-47	-48	-48	-48	-45	-31	-20	-10	-10	-8	-6	-5	-4	-3	-3	-4	-5	-6
1-15 AUG	-7	-9	-15	-26	-37	-44	-47	-48	-48	-48	-49	-47	-36	-23	-11	-10	-9	-7	-5	-4	-4	-4	-4	-5	-7
16-31 AUG	-7	-11	-19	-31	-40	-45	-47	-48	-48	-48	-49	-48	-41	-26	-13	-10	-9	-7	-6	-5	-4	-4	-5	-6	-7
1-15 SEP	-9	-14	-24	-35	-43	-46	-48	-48	-48	-49	-49	-49	-45	-30	-16	-10	-10	-8	-6	-5	-5	-5	-6	-7	-9
16-30 SEP	-11	-18	-30	-40	-45	-47	-48	-48	-48	-49	-49	-49	-48	-34	-20	-10	-11	-9	-7	-6	-6	-6	-7	-8	-11
1-15 OCT	-14	-24	-35	-43	-46	-48	-48	-48	-49	-49	-49	-49	-49	-41	-24	-11	-11	-10	-8	-7	-7	-7	-7	-9	-14
16-31 OCT	-18	-30	-39	-45	-47	-48	-48	-48	-49	-49	-49	-49	-49	-45	-30	-14	-11	-11	-9	-8	-7	-8	-8	-12	-18
1-15 NOV	-23	-33	-42	-46	-47	-48	-48	-48	-49	-49	-49	-49	-49	-48	-36	-20	-11	-12	-10	-9	-8	-9	-10	-15	-23
16-30 NOV	-27	-36	-43	-46	-48	-48	-48	-49	-49	-49	-49	-49	-49	-49	-41	-25	-11	-13	-12	-10	-9	-9	-12	-17	-27
1-15 DEC	-28	-37	-44	-46	-48	-48	-48	-49	-49	-49	-49	-49	-49	-49	-45	-29	-14	-13	-13	-10	-10	-10	-13	-19	-28
16-31 DEC	-28	-36	-43	-46	-48	-48	-48	-49	-49	-49	-49	-49	-49	-49	-47	-33	-16	-13	-14	-11	-10	-10	-13	-19	-28

LOCATION 40.0 N 148.0 W
STATION D NORTH DAKOTA

DATE	00	01	02	03	04	05	06	07	08	09	10	GMT 11	12	13	14	15	16	17	18	19	20	21	22	23	24
1-15 JAN	-25	-34	-42	-47	-49	-50	-50	-50	-51	-51	-51	-51	-51	-51	-49	-36	-20	-10	-12	-11	-9	-9	-11	-16	-25
16-31 JAN	-21	-31	-40	-47	-49	-50	-50	-50	-50	-51	-51	-51	-51	-51	-48	-34	-19	-10	-12	-10	-8	-8	-9	-13	-21
1-14 FEB	-16	-27	-37	-45	-48	-50	-50	-50	-50	-51	-51	-51	-51	-51	-45	-29	-14	-10	-10	-8	-7	-7	-8	-10	-16
15-29 FEB	-13	-22	-33	-42	-48	-49	-50	-50	-50	-51	-51	-51	-51	-50	-38	-23	-10	-10	-9	-7	-6	-6	-7	-8	-13
1-15 MAR	-11	-18	-30	-40	-47	-49	-50	-50	-50	-50	-51	-51	-51	-47	-32	-19	-8	-10	-8	-6	-5	-5	-6	-7	-11
16-31 MAR	-9	-15	-25	-37	-45	-48	-50	-50	-50	-50	-51	-51	-50	-41	-26	-12	-9	-8	-6	-5	-4	-4	-5	-6	-9
1-15 APR	-7	-12	-21	-33	-42	-47	-49	-50	-50	-50	-51	-51	-47	-32	-18	-9	-9	-7	-5	-4	-4	-4	-4	-5	-7
16-30 APR	-6	-10	-18	-30	-40	-47	-49	-50	-50	-50	-50	-50	-41	-27	-14	-9	-8	-6	-5	-3	-3	-3	-3	-5	-6
1-15 MAY	-6	-9	-15	-26	-37	-45	-48	-50	-50	-50	-50	-48	-35	-21	-10	-10	-8	-5	-4	-3	-2	-2	-3	-4	-6
16-31 MAY	-5	-7	-13	-23	-34	-43	-47	-49	-50	-50	-50	-43	-31	-18	-10	-9	-7	-5	-4	-2	-2	-2	-3	-4	-5
1-15 JUN	-5	-7	-12	-20	-32	-42	-47	-49	-50	-50	-50	-41	-29	-16	-11	-9	-7	-5	-3	-2	-2	-2	-2	-3	-5
16-30 JUN	-5	-6	-11	-19	-31	-41	-46	-49	-50	-50	-50	-41	-29	-16	-11	-9	-7	-5	-3	-2	-2	-2	-2	-3	-5
1-15 JUL	-5	-6	-11	-19	-31	-41	-47	-49	-50	-50	-50	-42	-30	-19	-10	-9	-7	-5	-3	-2	-2	-2	-2	-3	-5
16-31 JUL	-5	-7	-12	-21	-33	-42	-47	-49	-50	-50	-50	-46	-33	-21	-10	-9	-7	-5	-4	-3	-2	-2	-3	-4	-5
1-15 AUG	-5	-8	-14	-24	-36	-44	-48	-49	-50	-50	-50	-49	-38	-24	-13	-9	-8	-6	-4	-3	-2	-2	-3	-4	-5
16-31 AUG	-6	-10	-17	-29	-40	-46	-49	-50	-50	-50	-50	-50	-43	-28	-15	-9	-8	-7	-5	-4	-3	-3	-4	-5	-6
1-15 SEP	-7	-13	-23	-34	-43	-48	-49	-50	-50	-50	-51	-51	-47	-32	-18	-9	-9	-7	-5	-4	-4	-4	-4	-5	-7
16-30 SEP	-10	-17	-28	-39	-46	-49	-50	-50	-50	-50	-51	-51	-50	-36	-22	-9	-9	-8	-6	-5	-5	-5	-5	-6	-10
1-15 OCT	-13	-22	-34	-43	-48	-49	-50	-50	-50	-51	-51	-51	-51	-43	-28	-13	-9	-9	-7	-6	-5	-6	-6	-8	-13
16-31 OCT	-17	-28	-38	-46	-49	-50	-50	-50	-50	-51	-51	-51	-51	-47	-32	-17	-9	-10	-8	-7	-6	-7	-7	-11	-17
1-15 NOV	-22	-33	-42	-47	-49	-50	-50	-50	-51	-51	-51	-51	-51	-50	-39	-23	-10	-11	-10	-8	-7	-8	-9	-14	-22
16-30 NOV	-26	-35	-43	-48	-49	-50	-50	-50	-51	-51	-51	-51	-51	-51	-43	-28	-12	-11	-11	-9	-8	-8	-11	-17	-26
1-15 DEC	-27	-37	-44	-48	-49	-50	-50	-50	-51	-51	-51	-51	-51	-51	-47	-32	-17	-11	-12	-10	-9	-9	-12	-19	-27
16-31 DEC	-27	-36	-43	-48	-49	-50	-50	-50	-51	-51	-51	-51	-51	-51	-49	-35	-20	-11	-13	-11	-9	-9	-12	-18	-27

Figure B-5(b). Propagation Corrections Station D

10.2 KHZ OMEGA PROPAGATION CORRECTIONS IN UNITS OF CECS

LOCATION 40.0 N 144.0 W
STATION H JAPAN

DATE	GMT 00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1-15 JAN	-7	-6	-9	-19	-29	-40	-50	-60	-69	-74	-76	-77	-78	-78	-78	-78	-78	-69	-56	-47	-37	-22	-6	-6	-7
16-31 JAN	-6	-4	-7	-14	-25	-36	-46	-57	-67	-74	-76	-77	-77	-78	-78	-78	-78	-67	-55	-46	-35	-21	-3	-5	-6
1-14 FEB	-4	-3	-4	-9	-20	-31	-42	-53	-64	-72	-75	-77	-77	-78	-78	-78	-77	-66	-52	-42	-31	-16	-2	-4	-4
15-29 FEB	-2	-1	-2	-6	-15	-26	-38	-49	-60	-70	-75	-76	-77	-78	-78	-78	-75	-59	-50	-40	-26	-10	-1	-3	-2
1-15 MAR	-1	0	0	-3	-11	-22	-34	-45	-57	-68	-74	-76	-77	-77	-78	-78	-69	-55	-44	-34	-21	-5	-1	-2	-1
16-31 MAR	1	2	1	-1	-7	-18	-29	-41	-53	-65	-73	-76	-77	-77	-78	-77	-63	-49	-41	-28	-14	-1	-1	-1	1
1-15 APR	3	3	3	1	-4	-14	-25	-37	-49	-62	-71	-75	-77	-77	-78	-72	-56	-45	-34	-23	-8	0	-1	1	3
16-30 APR	4	4	4	2	-2	-11	-22	-33	-45	-59	-70	-74	-76	-77	-78	-64	-50	-40	-30	-17	-4	0	1	3	4
1-15 MAY	5	5	5	3	0	-8	-19	-30	-42	-55	-67	-73	-76	-77	-75	-58	-46	-36	-25	-13	-1	0	1	4	5
16-31 MAY	5	6	5	4	1	-6	-16	-27	-39	-52	-65	-72	-75	-77	-70	-54	-42	-33	-22	-9	-1	0	2	4	5
1-15 JUN	6	6	6	4	2	-4	-14	-24	-36	-49	-62	-71	-75	-76	-66	-52	-40	-32	-20	-7	0	0	2	5	6
16-30 JUN	6	6	6	4	2	-3	-13	-23	-35	-47	-61	-70	-74	-76	-66	-52	-40	-31	-20	-8	0	0	2	5	6
1-15 JUL	6	6	6	4	2	-4	-13	-24	-35	-48	-61	-70	-75	-76	-70	-53	-42	-32	-23	-9	-1	0	2	4	6
16-31 JUL	5	6	5	4	2	-5	-14	-25	-37	-50	-63	-71	-75	-77	-73	-56	-44	-34	-24	-13	0	0	2	4	5
1-15 AUG	5	5	5	3	0	-7	-17	-28	-40	-54	-66	-73	-76	-77	-77	-60	-48	-38	-27	-14	-2	-1	1	3	5
16-31 AUG	4	4	4	2	-2	-10	-21	-33	-45	-58	-69	-74	-76	-77	-77	-67	-51	-41	-29	-18	-5	0	0	2	4
1-15 SEP	3	3	2	1	-5	-15	-27	-38	-51	-64	-72	-75	-77	-77	-78	-72	-56	-44	-34	-23	-8	0	-1	1	3
16-30 SEP	1	2	1	-2	-10	-21	-32	-44	-56	-68	-74	-76	-77	-77	-78	-76	-59	-47	-37	-26	-12	0	-2	0	1
1-15 OCT	0	0	-1	-6	-15	-27	-38	-50	-62	-71	-75	-77	-77	-78	-78	-77	-63	-52	-41	-29	-16	-1	-2	-2	0
16-31 OCT	-2	-2	-3	-10	-21	-32	-43	-55	-66	-73	-76	-77	-77	-78	-78	-78	-69	-55	-45	-34	-20	-3	-3	-4	-2
1-15 NOV	-4	-3	-7	-15	-26	-37	-48	-59	-69	-74	-76	-77	-78	-78	-78	-78	-73	-60	-48	-39	-25	-9	-3	-5	-4
16-30 NOV	-5	-5	-9	-19	-30	-41	-51	-61	-70	-75	-77	-77	-78	-78	-78	-78	-76	-64	-53	-43	-30	-15	-3	-6	-5
1-15 DEC	-7	-6	-11	-22	-32	-43	-52	-63	-71	-75	-77	-77	-78	-78	-78	-78	-78	-68	-56	-46	-34	-19	-4	-7	-7
16-31 DEC	-7	-7	-11	-22	-33	-42	-51	-62	-71	-75	-77	-77	$\boxed{-78}$	-78	-78	-78	-78	-70	-58	-47	-37	-25	-4	-7	-7

LOCATION 40.0 N 148.0 W
STATION H JAPAN

DATE	GMT 00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1-15 JAN	-7	-6	-8	-16	-27	-38	-48	-58	-67	-73	-75	-75	-76	-76	-76	-76	-76	-72	-58	-48	-37	-23	-6	-7	-7
16-31 JAN	-6	-5	-6	-12	-23	-34	-44	-55	-65	-72	-74	-75	-76	-76	-76	-76	-76	-70	-58	-47	-35	-21	-4	-6	-6
1-14 FEB	-4	-3	-4	-8	-18	-29	-40	-51	-62	-70	-74	-75	-76	-76	-76	-76	-76	-65	-53	-44	-31	-16	-3	-5	-4
15-29 FEB	-3	-2	-2	-5	-13	-24	-36	-47	-59	-68	-73	-75	-75	-76	-76	-76	-75	-61	-48	-38	-26	-11	-2	-4	-3
1-15 MAR	-1	0	-1	-3	-9	-20	-32	-43	-55	-66	-72	-74	-75	-76	-76	-76	-72	-56	-46	-33	-21	-6	-2	-3	-1
16-31 MAR	1	1	1	-1	-6	-16	-28	-39	-52	-64	-71	-74	-75	-76	-76	-76	-65	-51	-39	-29	-15	-1	-2	-1	1
1-15 APR	2	3	2	1	-3	-13	-24	-35	-48	-61	-70	-73	-75	-76	-76	-74	-57	-46	-34	-23	-8	-1	-1	1	2
16-30 APR	3	4	3	2	-2	-10	-20	-32	-44	-57	-68	-72	-75	-75	-76	-67	-51	-40	-29	-17	-3	-1	0	2	3
1-15 MAY	4	5	4	3	0	-7	-17	-28	-41	-54	-66	-72	-74	-75	-75	-61	-47	-36	-26	-14	-1	-1	1	3	4
16-31 MAY	5	5	5	3	1	-5	-15	-26	-37	-51	-63	-70	-74	-75	-74	-55	-43	-33	-23	-11	-1	-1	1	3	5
1-15 JUN	5	5	5	4	1	-4	-12	-23	-35	-48	-61	-69	-73	-75	-71	-53	-41	-32	-22	-10	-2	-1	2	4	5
16-30 JUN	5	6	5	4	2	-3	-11	-22	-33	-46	-60	-69	-73	-75	-71	-54	-41	-32	-22	-9	-2	-1	2	4	5
1-15 JUL	5	5	5	4	2	-3	-12	-22	-34	-46	-60	-69	-73	-75	-73	-54	-42	-33	-24	-11	-2	-1	1	4	5
16-31 JUL	5	5	5	3	1	-4	-13	-24	-35	-48	-62	-70	-73	-75	-75	-58	-46	-35	-25	-13	-2	-1	1	3	5
1-15 AUG	4	5	4	3	0	-6	-16	-27	-39	-52	-64	-71	-74	-75	-76	-64	-49	-38	-28	-16	-3	-1	0	2	4
16-31 AUG	3	4	3	2	-1	-9	-20	-31	-43	-57	-68	-72	-74	-75	-76	-69	-53	-41	-31	-20	-5	-1	-1	2	3
1-15 SEP	2	3	2	1	-4	-14	-25	-37	-49	-62	-70	-74	-75	-76	-76	-73	-57	-46	-34	-23	-8	-1	-1	1	2
16-30 SEP	1	1	1	-2	-8	-19	-31	-42	-55	-66	-72	-74	-75	-76	-76	-75	-61	-48	-38	-26	-12	-1	-2	-1	1
1-15 OCT	-1	0	-1	-5	-13	-25	-36	-48	-60	-69	-73	-75	-76	-76	-76	-76	-65	-51	-41	-30	-16	-2	-3	-2	-1
16-31 OCT	-2	-2	-3	-8	-19	-30	-42	-53	-64	-72	-74	-75	-76	-76	-76	-76	-70	-57	-44	-33	-21	-4	-4	-4	-2
1-15 NOV	-4	-3	-6	-13	-24	-35	-46	-58	-67	-73	-75	-75	-76	-76	-76	-76	-74	-60	-49	-39	-25	-9	-4	-5	-4
16-30 NOV	-5	-5	-8	-17	-28	-39	-49	-60	-69	-73	-75	-75	-76	-76	-76	-76	-76	-64	-52	-42	-30	-14	-4	-7	-5
1-15 DEC	-7	-6	-10	-19	-30	-40	-50	-61	-69	-73	-75	-76	-76	-76	-76	-76	-76	-68	-55	-45	-34	-19	-5	-7	-7
16-31 DEC	-7	-6	-10	-19	-30	-40	-49	-60	-69	-73	-75	-75	-76	-76	-76	-76	-76	-70	-57	-47	-36	-22	-5	-7	-7

Figure B-5(c). Propagation Corrections Station H

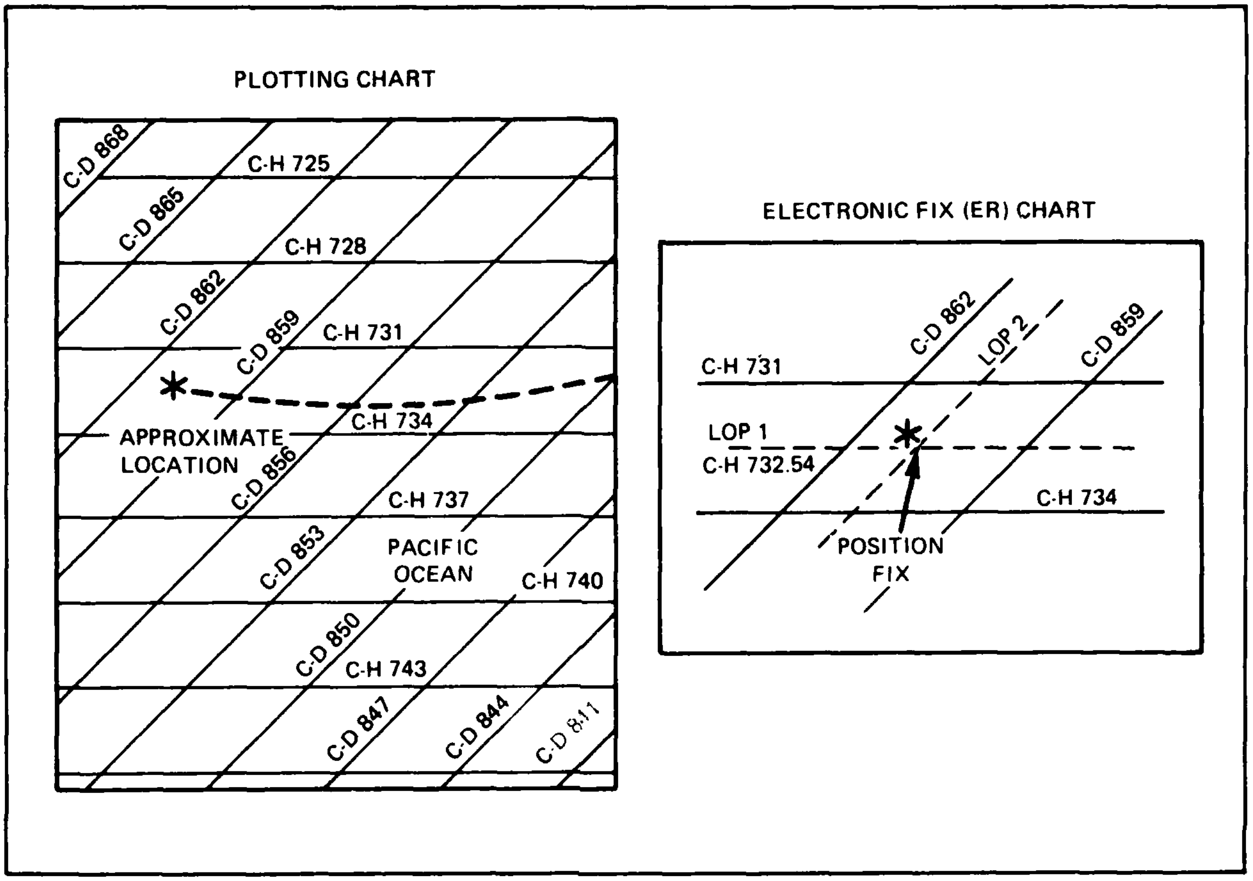


Figure B-6. Simplified OMEGA Position Fix Chart

APPENDIX C: DIFFERENTIAL OMEGA

OMEGA, with an accuracy of 4 nautical miles, is satisfactory for transoceanic or transcontinental navigation, but not for coastal piloting or terminal approach. As discussed in the signal propagation section of this Users Guide, phase errors in transmission can be corrected on a long-term average basis, but not for small local anomalies introduced along the transmission path from the transmitter to receiver. However, since OMEGA receivers on ships or planes located relatively near to each other and using the same OMEGA frequencies and station pairs will experience the same propagation anomalies, a rendevous based on OMEGA navigation will show a significantly higher accuracy than the corresponding absolute position determination. This regional or spatial correlation in the propagation errors of the OMEGA signal provides the foundation for Differential OMEGA. The status of the Differential OMEGA stations is listed in Table C-1.

Differential OMEGA enhances the accuracy of the OMEGA Navigation System by providing realtime phase corrections to Differential OMEGA users in a limited area. A Differential OMEGA station is established at a precisely known location. The receiver measures the instantaneous local propagation variations by comparing its measured OMEGA signals to those expected for its known location. The variations are caused by changes in propagation speed due to changes in ionospheric parameters and topography. The phase of each received station signal is then corrected to reflect the established position of the receiver. These corrections are then transmitted by a radiobeacon to all users in the Differential area.

The accuracy of the system is directly proportional to the distance from the Differential OMEGA station. Accuracies for the system on the order of three tenths of a nautical mile within 50 nm from the station gradually deteriorating to 1 nm at 500 nm from the station have been demonstrated. The range of a station is dependent upon the range of the radiobeacon being utilized to transmit the Differential signal and generally exhibits a three-to-one relationship. Therefore, differential reception would extend to a radius of 150 nm for a 50 nm radius beacon or to a 450 nm radius for a 150 nm beacon.

There are currently 14 operational Differential OMEGA stations (indicated in Figure C-1) and 3 planned stations, also indicated in Figure C-1 for Dakar, French Guiana, and Guadelope*. These stations were manufactured and installed by the Sercel Corporation of France.

A Differential OMEGA system consists of a reference station and a monitor station. The purpose of the reference station is to determine the realtime phase corrections necessary to compensate for the propagation variations in the local area and to encode these corrections on the radiobeacon's signal. The reference station consists of two reception/correction processing units, one principle and one standby. These units receive the OMEGA signal transmission from as many as all eight of the stations, compute the correction for each station and transfer this data to the pilot unit. The correction unit is also programmed to eliminate OMEGA stations which are not receivable, modally or long path affected. The pilot and commutation unit generates the radiobeacon frequency and modulates that carrier with a 20 Hz signal for encoding the real-time phase corrections. These signals are provided to the primary and secondary modes of the radiobeacon for transmission. A printer provides an output of the status of the reference station and the OMEGA signal quality.

The second component of the Differential OMEGA system is the remote monitoring station. The monitor performs two functions: it provides an operator access to the data representing the general operational situation of the system and a readout of the synthesis of observations made by the monitoring station during the preceding 24 hours; the second function is a recording of preprocessed data to establish statistics for progressively improving the systems accuracy and operation.

The remote monitoring station consists of the following equipment. An M6 unit receives the Differential transmission. In addition to displaying latitude, longitude, station reception levels, fix quality, etc., the M6 provides two data ouputs. One output is to the cassete recorder which is located directly above the M6 unit for recording raw data for technical statistics and program improvement.

---

* A Differential OMEGA station was also installed on September 1982 at Punta Tuna, Puerto Rico for an operational evaluation by the U.S. Coast Guard. The station will be made a permanent operational facility.

The second output is to the processor. The HP 85 processor displays average and standard deviations in nautical miles of latitude and longitude from the monitors exact location on an hourly basis, a graphical representation of this, the average signal strength for each station at 10.2 kHz and for Differential OMEGA and the signal strength in DB of the Differential transmission. It also has the ability to record this data and it controls telephone calls through the modem. The modem allows interrogation of the monitor station's information at a distant location by a telephone call.

TABLE C-1. DIFFERENTIAL OMEGA STATIONS STATUS 1982

Station Name	Gov't	Code	Freq. (kHz)	Radio-Beacon Mode	Ident.	Latitude	Longitude	Range (nm)	Transmitted Corrections After 12/80	On the Air Date
OPERATIONAL STATIONS (14)										
YEU	FRANCE	9/0	312.6	CW-A2	YE	46°43'05"N	2°22'55"W	270	ABDEFH	6/75
CREACH (OUESSANT)	FRANCE	10/6	308.0	SEQ-A2 1/6-H + 5	CA	48°27'33"N	5°07'39"W	270	ABDEFH	4/78
PORQUEROLLES	FRANCE	11/3	313.5	SEQ-A1 2/6-H + 4	PQ	42°58'59"N	6°12'21"E	400	ABDEFH	12/76
LAGOS	PORTUGAL	12/0	364.0	CW-A2	LGS	37°09'33"N	8°36'52"W	500	ABCDFH	2/78
PORTO SANTO MADEIRA	PORTUGAL	13/0	338.0	CW-A2	PST	33°03'44"N	16°21'25"W	500	ABCDFH	2/79
HORTA ACORES	PORTUGAL	14/0	380.0	CW-A2	FIL	38°31'13"N	28°41'18"W	400	ABCDF	2/79
CAP BON	TUNISIA	15/7	313.5	SEQ-A1 2/6-H + 0	BN	37°04'13"	11°02'34"E	400	ABDEFH	3/80
GRIS NEZ	FRANCE	16/5	310.3	SEQ-A2 1/6-H + 4	GN	50°52'10"N	01°35'01"E	150	ABDEFH	5/80
GALANTRY ST. PIERRE	FRANCE	17/0	342.0	CW-A2	Y	46°45'56"N (Approx.)	56°09'17"W (Approx.)	300	ABCDF	8/80
PORT BOUET ABIDJAN	IVORY COAST	18/0	294.2	CW-A2	PB	05°14'N (Approx.)	03°56' W (Approx.)	300	ABCDEF	1/81
CABO FINISTERRE	SPAIN	22/2	310.3	SEQ-2 2/6-H + 2	FI	42°52'51"N	9°16'17"W	270	ABDEFH	3/82
LA ISTETA CANARIA	SPAIN	23/7	291.9	SEQ A2 2/6-H + 0	LT	28°10'18"N	15°25'08"W	300	ABCDFH	4/82
CABO DE PALOS	SPAIN	24/2	294.2	SEQ A2 2/6 H + 2	PA	37°38'06"N	00°41'23"W	150	ABDEFH	4/82
PUNTA TUNA PUERTO RICO	U.S.	N/A	288.0	CW	PRC	17°59'17"N	65°53'07"W	450	ABCDFG	9/82
PLANNED STATIONS (3)										
DAKAR	SENEGAL	19/0				14°43'N (Approx.)	17°28'W (Approx.)	300	ABCDEF	
CAYENNE GUYANE	FRANCE	20/1	327	A1	FXC	04°49'31"N	52°21'54"W	300	ABCDFG	
POINTE A PITRE (GUADELOUPE)	FRANCE	21/1		A1				300	ABCDFH	

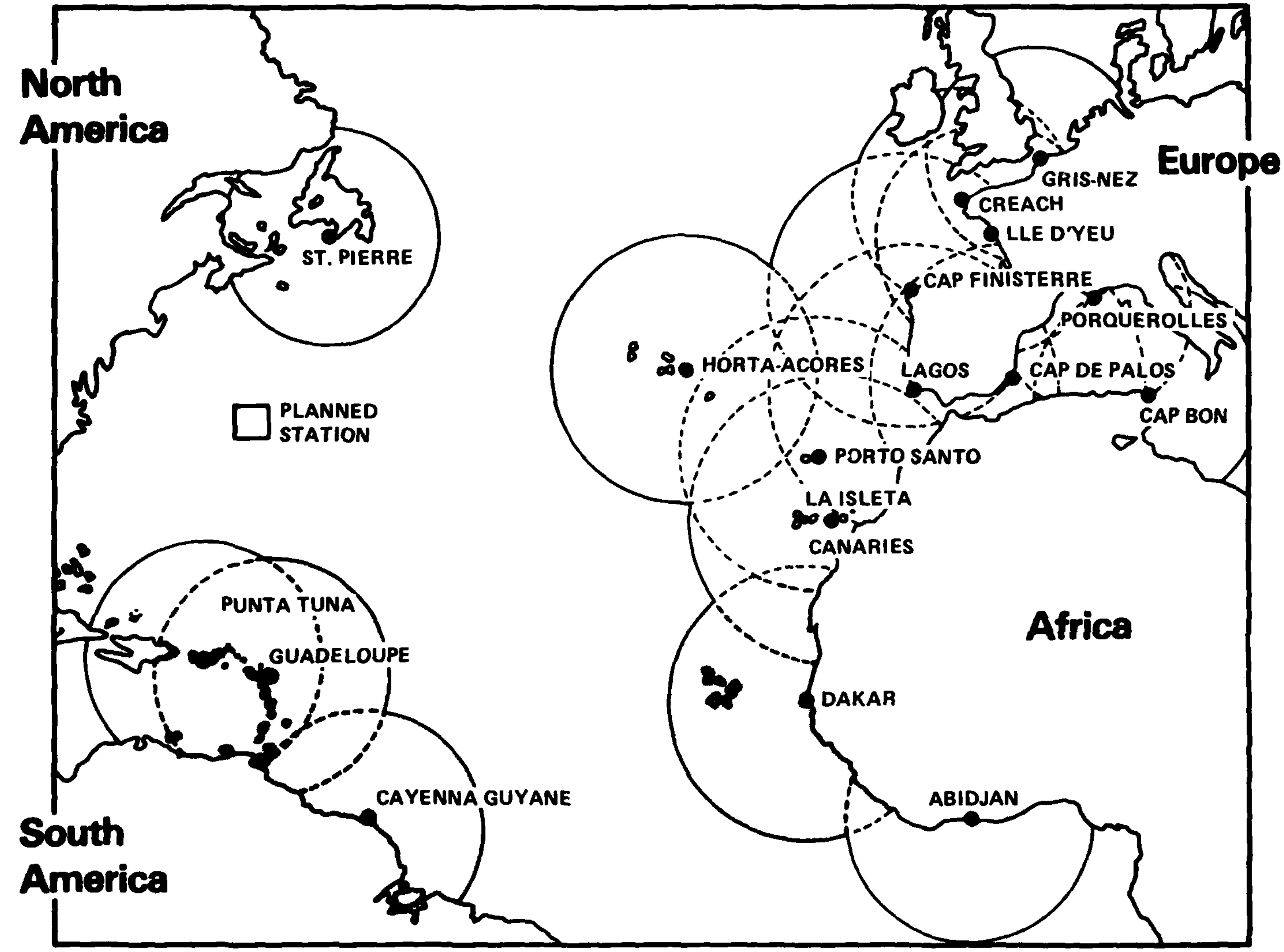


Figure C-1. Differential OMEGA Coverage

APPENDIX D: GLOSSARY OF TERMS

Baseline Great-circle line connecting two transmitting stations.

Boundaries or Lane Crossing Phase difference between two stations equals zero.

Centicycle One hundredth of a cycle; OMEGA receivers may display position in terms of centicycles from the lane boundary. Abbreviated CEC.

Centilane One hundredth of a lane. Receiver readings which have been corrected for propagation conditions can be directly plotted on OMEGA charts which have centilane or full lane units. Abbreviated CEL.

Cycle The change of an alternating wave from zero then a positive peak then to zero and then to a negative peak and back to zero. A signal frequency is measured in cycles per second. The unit is the hertz (Hz). A kilohertz (kHz) = 1000 Hz. A megahertz (MHz) = 1000 kHz.

Hyperbola A curve that intersects all points that have a constant difference in distance from two fixed points.

Initialization Setting a known position or value into a receiver before starting a flight or voyage.

Ionosphere Electrified layer in the upper atmosphere. OMEGA signals are reflected from the lowest or D layer which is found at altitudes from 70 to 90 kilometers.

Kilohertz 1000 Hz

Lane A charting unit which defines one complete phase interval (i.e., 0° to 360°). In the OMEGA system, lanes are defined as a complete cycle in relative signal phase.

Latitude/ Longitude Universal grid network for navigation purposes in terms of degrees, minutes and seconds for establishing position above or below the equator or east/west of the prime meridian in Greenwich, England.

Lattice A pattern formed by two or more families of intersecting lines such as the hyperbolic lines of position from three or more OMEGA stations.

Megahertz 1×10^6 Hz.

Modal Interference A condition in which two or more mode patterns combine and mutually interfere resulting in phase distortions and a reduction in signal strength at that point. This occurs near transmitting stations and also on some nighttime propagation paths.

Mode One of the several types of eletromagnetic wave patterns which can be found in the cavity formed by the ionosphere and the earth's surface. Each mode has a different pattern of electrical and magnetic fields.

Nautical Mile 6080 feet.

Nominal Phase or Charted Phase The OMEGA signal phase at a point based on an assumed phase velocity which is 0.9974 times the speed of light.

Polar Cap Anomaly A depression of the auroral ionospheres, those regions of the ionosphere within about a 25 degrees radius of the magnetic poles, caused by proton showers emanating from solar flares. The effect is to cause increased phase velocity (phase advance) along OMEGA signal paths traversing the auroral zones.

Propagation	The transfer of electromagnetic energy though a medium, also called wave propagation.
Propagation Correction	The corrections based on the predicted characteristics of the signal path required to correct an actual OMEGA receiver reading to the conditions for which the OMEGA navigation charts are based. Abbreviated PPC
Sudden Ionospheric Disturbances	A depression of the illuminated (sunlit) ionosphere caused by X-ray emission from solar flares causes increased phase velocity along OMEGA signal paths traversing the sunlit hemisphere. Abbreviated SID.
Symmetric	Equal distribution on opposite sides of a plane of reference.
Synchronous	Coinciding or occurring at the same time.
Transition	The period when the signal path between the transmitting station and the receiver is only partially illuminated. In this case the sunrise or sunset line lies between receiver and transmitter. The duration of the transition interval will depend on the location of the transmitter and receiver, the orientation of the baseline and the time of year.
Wavelength	Velocity/frequency where the velocity = 186,000 mi/sec or 3×10^8 meter/sec, the distance in the line of advance of a wave from any point to its next point of corresponding phase.